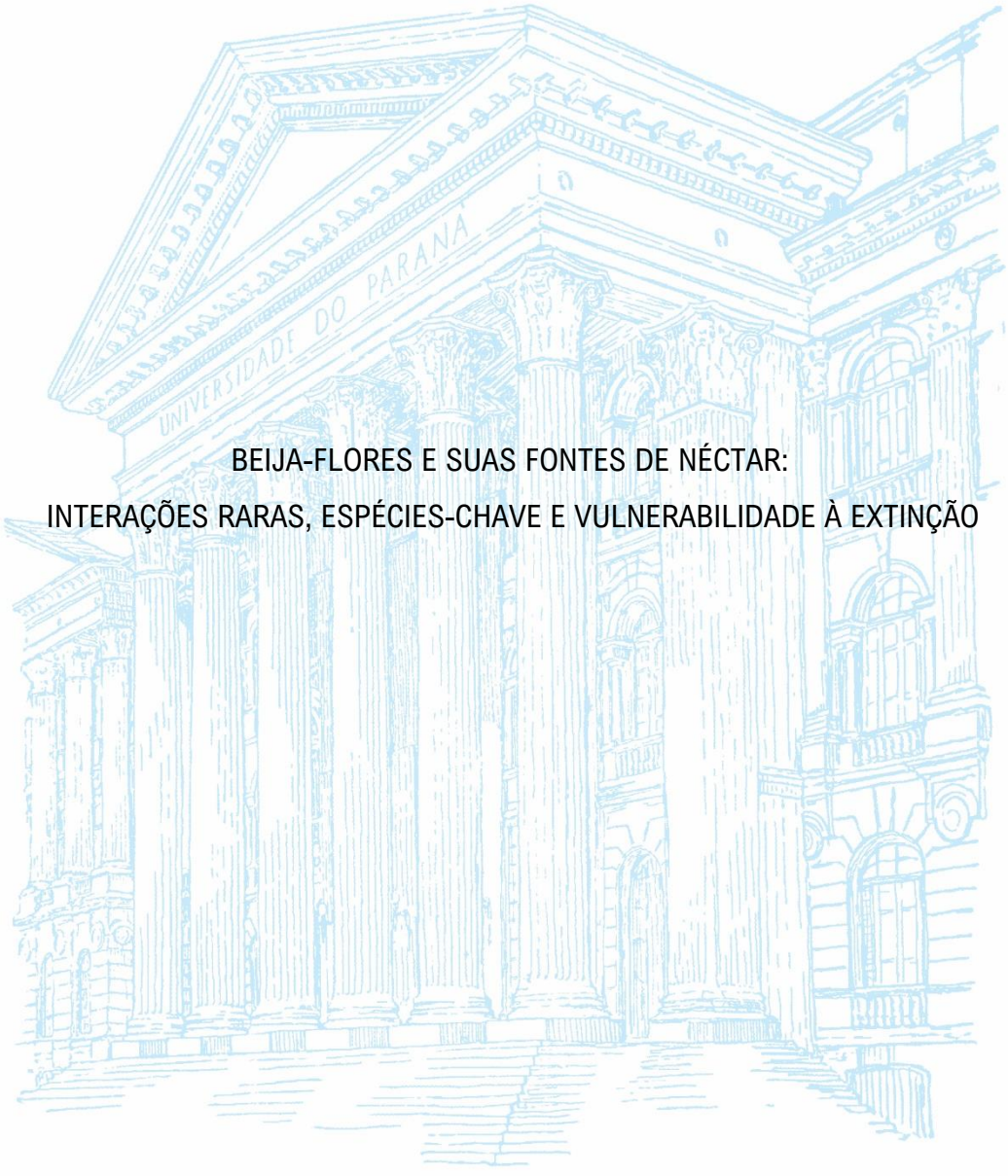
UNIVERSIDADE FEDERAL DO PARANÁ

THAIS BASTOS ZANATA



BEIJA-FLORES E SUAS FONTES DE NÉCTAR:
INTERAÇÕES RARAS, ESPÉCIES-CHAVE E VULNERABILIDADE À EXTINÇÃO

CURITIBA

2018

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BEIJA-FLORES E SUAS FONTES DE NÉCTAR:
INTERAÇÕES RARAS, ESPÉCIES-CHAVE E VULNERABILIDADE À EXTINÇÃO

Tese apresentada como requisito parcial à obtenção do título de Doutora em Ecologia e Conservação, no Curso de Pós-Graduação em Ecologia e Conservação do Setor de Ciências Biológicas da Universidade Federal do Paraná.

Orientadora: Prof.ª Dr.ª Isabela Galarda Varassin
Co-orientador: Prof. Dr. Bo Dalsgaard

CURITIBA

2018

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Zanata, Thais Bastos
Beija-flores e suas fontes de néctar: interações raras, espécies chave e vulnerabilidade à extinção. – Curitiba, 2018.
190 p.: il. ; 30cm.

Orientadora: Isabela Galarda Varassin
Co-orientador: Bo Dalsgaard
Tese (Doutorado) - Universidade Federal do Paraná, Setor de Ciências Biológicas. Programa de Pós-Graduação em Ecologia e Conservação.

1. Beija-flor. 2. Polinização. 3. Conservação. I. Título. II. Varassin, Isabela Galarda. III. Dalsgaard, Bo. IV. Universidade Federal do Paraná. Setor de Ciências Biológicas. Programa de Pós-Graduação em Ecologia e Conservação.

CDD (20. ed.) 581.16

MINISTÉRIO DA EDUCAÇÃO
SETOR CIÊNCIAS BIOLÓGICAS
UNIVERSIDADE FEDERAL DO PARANÁ
PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃO
PROGRAMA DE PÓS-GRADUAÇÃO ECOLOGIA E CONSERVAÇÃO

ATA Nº10

ATA DE SESSÃO PÚBLICA DE DEFESA DE DOUTORADO PARA A OBTENÇÃO DO GRAU DE DOUTOR EM ECOLOGIA E CONSERVAÇÃO

No dia vinte e oito de março de dois mil e dezoito às 14:00 horas, na sala Secretaria PPGECO, Setor de Ciências Biológicas, foram instalados os trabalhos de arguição da doutoranda **THAIS BASTOS ZANATA** para a Defesa Pública de sua tese intitulada **Beija-flores e suas fontes de néctar: interações raras, espécies-chave e vulnerabilidade à extinção**. A Banca Examinadora, designada pelo Colegiado do Programa de Pós-Graduação em ECOLOGIA E CONSERVAÇÃO da Universidade Federal do Paraná, foi constituída pelos seguintes Membros: ISABELA GALARDA VARASSIN (UFPR), LUÍSA MAFALDA GIGANTE RODRIGUES CARVALHEIRO (UFG), MARINA WOLOWSKI TORRES (UNIFAL), MARCOS BERGMANN CARLUCCI (UFPR), MARCO AURELIO RIBEIRO DE MELLO (UFMG), . Dando início à sessão, a presidência passou a palavra a discente, para que a mesma expusesse seu trabalho aos presentes. Em seguida, a presidência passou a palavra a cada um dos Examinadores, para suas respectivas arguições. A aluna respondeu a cada um dos arguidores. A presidência retomou a palavra para suas considerações finais. A Banca Examinadora, então, reuniu-se e, após a discussão de suas avaliações, decidiu-se pela APROVAÇÃO da aluna. A doutoranda foi convidada a ingressar novamente na sala, bem como os demais assistentes, após o que a presidência fez a leitura do Parecer da Banca Examinadora. A aprovação no rito de defesa deverá ser homologada pelo Colegiado do programa, mediante o atendimento de todas as indicações e correções solicitadas pela banca dentro dos prazos regimentais do programa. A outorga do título de doutor está condicionada ao atendimento de todos os requisitos e prazos determinados no regimento do Programa de Pós-Graduação. Nada mais havendo a tratar a presidência deu por encerrada a sessão, da qual eu, ISABELA GALARDA VARASSIN, lavrei a presente ata, que vai assinada por mim e pelos membros da Comissão Examinadora.

Curitiba, 28 de Março de 2018.

ISABELA GALARDA VARASSIN
Presidente da Banca Examinadora

LUÍSA MAFALDA GIGANTE RODRIGUES CARVALHEIRO
Avaliador Externo

MARINA WOLOWSKI TORRES
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TERMO DE APROVAÇÃO

Os membros da Banca Examinadora designada pelo Colegiado do Programa de Pós-Graduação em ECOLOGIA E CONSERVAÇÃO da Universidade Federal do Paraná foram convocados para realizar a arguição da tese de Doutorado de **THAIS BASTOS ZANATA** intitulada: **Beija-flores e suas fontes de néctar: interações raras, espécies-chave e vulnerabilidade à extinção**, após terem inquirido a aluna e realizado a avaliação do trabalho, são de parecer pela sua APROVAÇÃO no rito de defesa.

A outorga do título de doutor está sujeita à homologação pelo colegiado, ao atendimento de todas as indicações e correções solicitadas pela banca e ao pleno atendimento das demandas regimentais do Programa de Pós-Graduação.

Curitiba, 28 de Março de 2018.

ISABELA GALARDA VARASSIN
Presidente da Banca Examinadora

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MARCO AURELIO RIBEIRO DE MELLO
Avaliador Externo

Dedico este trabalho ao meu pai, **Angelo A. Zanata**, cujo apoio e amor me permitiram realizar este sonho.

AGRADECIMENTOS

O doutorado foi um intenso caminho percorrido ao longo de quatro anos e foram as pessoas que encontrei nesta caminhada que tornaram esta experiência mais especial. E são a elas que eu agradeço:

Isabela G. Varassin, obrigada pela generosidade em me ensinar a ser uma pesquisadora. Seu carinho, calma e compreensão tornaram leves até os momentos mais tensos desta caminhada.

Bo Dalsgaard, obrigada por me ensinar a fazer ciência desde o primeiro contato durante o mestrado. Obrigada também por me receber no *Center for Macroecology, Evolution and Climate*, onde pude aprender mais sobre Ecologia com você e com outros grandes pesquisadores.

Laboratório de Ecologia Vegetal, obrigada pela alegria que vocês trouxeram aos meus dias, com as discussões científicas, bolos, risadas e festas. Obrigada também pela paciência com as minhas perguntas sem fim. Levo comigo o meu "temido caderninho", cheio de anotações das nossas reuniões, que servirão de estímulo para projetos futuros. Vocês sempre serão minha inspiração! Mas preciso agradecer especialmente àqueles que tiraram muitas das minhas dúvidas e que compartilharam e escutaram as minhas angústias científicas: Tiago S. Machado, Vinicius M. da Silva, Ricardo A. C. Oliveira, Israel Schneiberg, Luciana C. Franci e Victor P. Zwiener. Muito obrigada! Sem vocês o processo teria sido muito mais difícil. E é claro, muito obrigada, Tiago S. Malucelli, por toda a ajuda no R e por todos os "vai dar tudo certo" nas etapas finais do doutorado.

Márcia C. Marques, obrigada por me ensinar a fazer ciência através das reuniões do laboratório, mas acima disso, obrigada por me ensinar a ser uma cientista mulher. Você sempre será uma das minhas inspirações na luta pelo espaço feminino na academia.

James J. Roper, André C. Guaraldo, Guilherme D. S. Seger, Marcos B. Carlucci, Luiz H. Varzinczak, Jeferson V. Bugoni, Pietro K. M. Mendonça, Maurício O. Moura, André A. Padial e Fernanda T. Brum, obrigada por toda ajuda e discussões científicas ao longo do doutorado.

Jeferson V. Bugoni, Luísa G. Carvalheiro, Marco A. Mello, Marcos B. Carlucci, Marina Wolowski Torres e Maurício O. Moura, obrigada por terem aceito compor a banca de avaliação, pelas correções e sugestões para melhoria da tese.

Luisa F. L. Latorre e Paula V. Stica, muito obrigada pela paciência e pela oportunidade de aprender a ensinar. Embora o meu papel tenha sido ensinar um pouco do que sei a vocês, sinto que durante este período eu aprendi muito mais do ensinei.

Obrigada ao CNPq, ao *Danish Council for Independent Research Natural Sciences* e ao *Center for Macroecology Evolution and Climate* pelo financiamento das visitas aos museus para coleta dos dados morfológicos.

Alexandre Aleixo (Museu Paraense Emílio Goeldi, Belém, Brasil), Gary Graves (Smithsonian National Museum of Natural History, Washington, USA), Gerald Mayr (Senckenberg Naturmuseum Frankfurt, Frankfurt, Germany), John Bates (Field Museum of Natural History, Chicago, USA), Jon Fjeldså (Zoologisk Museum, Statens Naturhistoriske Museum, Copenhagen, Denmark), Juliana Paulo da Silva (Museu de Biologia Mello Leitão, Santa Teresa, Brasil), Karl-Ludwig Schuchmann (Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany), Marcos Raposo (Museu Nacional, Rio de Janeiro, Brasil), Mark Adams (Natural History Museum of Tring, Tring, UK), Paul Sweet (American Museum of Natural History, New York, USA), Robert Prys-Jones (Natural History Museum of Tring, Tring, UK) e Till Töpfer (Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany), obrigada por permitirem a minha visita aos museus para coleta dos dados morfológicos.

Alan D. C. Moura, Allan Timmermann, Aline G. Coelho, Ana Maria M. Gonzalez, Ana M. Rui, Andrea C. Araújo, Andrea Barquero, Bo Dalsgaard, Boris Tinoco, Caio G. Machado, Carlos Lara, Erich Fischer, Flor Maria G. Las-Casas, Genilda M. Oliveira, Glauco Kohler, Jeferson V. Bugoni, Juan F. Ornelas, Licléia C. Rodrigues, Liliana R. Lasprilla, Márcia Rocca, Marlies Sazima, Maria A. Maglianesi, Monica B. Ramirez, Oscar H. M. Gómez, Paulo E. Oliveira, Pete Cotton, Pietro K. Maruyama, Raul O. Pulido, Ruben Alarcon, Stefan Abrahamczyk, Stella Watts, Tanja T. Ingversen e Tiago S. Malucelli, obrigada por compartilharem os dados não publicados das interações entre beija-flores e plantas.

Obrigada à CAPES e ao PPG em Ecologia e Conservação da UFPR pela bolsa de doutorado e doutorado sanduíche. Mas acima disso, obrigada aos brasileiros que pagam seus impostos e que financiam a ciência feita no país.

E finalmente, obrigada à minha família e amigos, que são a minha maior fonte de alegria e amor.

“The important thing is not to stop questioning. Curiosity has its own reason for existence”.

(Albert Einstein)

RESUMO

Beija-flores são aves nectarívoras que polinizam mais de 1.300 espécies de plantas nas Américas, desempenhando um importante papel na manutenção da biodiversidade. As questões exploradas nesta tese foram norteadas pela seguinte ameaça à biodiversidade: a extinção das interações mutualísticas, como a polinização realizada pelos beija-flores. Considerando este problema e a importância dos beija-flores como polinizadores, no primeiro capítulo investigamos a vulnerabilidade das interações raras entre beija-flores e plantas, uma vez que interações raras tendem a ser mais vulneráveis à extinção do que interações redundantes. Para isso, utilizamos 74 redes de interação entre beija-flores e plantas distribuídas ao longo de um amplo gradiente latitudinal (38°N–31°S). Encontramos que beija-flores pertencentes a linhagens raras e que possuem morfologias distintas tendem a realizar interações raras, além de evitarem co-extinções, uma vez que realizam interações não redundantes. No segundo capítulo, descrevemos as características das espécies-chave de beija-flores nas redes de interação, já que espécies-chave contribuem para a manutenção das interações no sistema. Detectamos que beija-flores com bico curto e reto, tamanho alar grande, que possuem maior frequência de interação com as plantas e pertencentes aos clados dos *Bees, Emeralds* e *Mangoes* tendem a ser espécies-chave nas redes de interação. E finalmente, no terceiro capítulo, testamos quais características estão associadas à vulnerabilidade à extinção de 341 espécies de beija-flores. Encontramos que beija-flores com bico curto e reto e pertencentes a linhagens evolutivas comuns possuem maior vulnerabilidade à extinção. Dessa forma, considerando os resultados obtidos, detectamos as seguintes vulnerabilidades no sistema de polinização de beija-flores: as interações raras e a estabilidade do sistema são garantidas por espécies não redundantes evolutiva e morfologicamente e que atributos morfológios das espécies-chave estão associados a vulnerabilidade à extinção dos beija-flores.

Palavras-chave: Centralidade. Conservação. Espécies ameaçadas. Extinção. Polinização. Interação animal-planta. Raridade.

ABSTRACT

Hummingbirds are nectar-feeding birds that pollinate more than 1,300 plant species in the Americas, performing an essential role for the maintenance of biodiversity. The questions explored in this thesis were guided by the following biodiversity threat: the extinction of mutualistic interactions, like the pollination by hummingbirds. Considering this threat and the importance of hummingbirds as pollinators, in the first chapter we explored the vulnerability of rare interactions between plants and hummingbirds, since rare interactions tend to be more vulnerable to extirpation than redundant interactions. To answer this question, we used 74 plant-hummingbird interaction networks widely distributed across the Americas (38°N–31°S). We found that hummingbirds belonging to rare evolutionary lineages and having distinct morphologies tend to perform rare interaction, and are also those preventing secondary extinctions, since they perform non-redundant interactions. In the second chapter, we described the characteristics of keystone hummingbird species in the networks, since keystone species tend to prevent the extinction of mutualistic interactions. We detected that hummingbirds with short and straight bills, large wing chords, interacting more with their nectar resources and belonging to the clades of Bees, Emeralds and Mangoes tend to be keystone species in the networks. And finally, in the third chapter, we tested which characteristics are associated with the vulnerability to extinction of 341 hummingbird species. We found that hummingbirds with short and straight bills and belonging to common evolutionary lineages have higher vulnerability to extinction. Considering these results, we detected the following threats to the pollination system of hummingbirds: rare interactions and system stability being performed by non-redundant evolutionary and morphologically species and the tendency of the morphological traits of keystone species to be also associated with the extinction vulnerability of hummingbirds.

Keywords: Centrality. Conservation. Extinction. Pollination. Plant-animal interaction. Rarity. Threatned species.

LISTA DE FIGURAS

CAPÍTULO 1

CAPÍTULO 2

CAPÍTULO 3

LISTA DE TABELAS

CAPÍTULO 1

CAPÍTULO 2

CAPÍTULO 3

SUMÁRIO

INTRODUÇÃO GERAL

Os beija-flores, as plantas que visitam para obtenção de néctar e a interação mutualística resultante destas visitas são o objeto de estudo desta tese. É através das visitas às flores que os beija-flores obtêm recurso energético essencial à sua sobrevivência e as plantas garantem a polinização de suas flores (Stiles 1978). Beija-flores são aves pertencentes à família Trochilidae (Aves: Apodiformes), um grupo monofilético originado há aproximadamente 22 milhões de anos nas terras baixas da América do Sul (McGuire et al. 2014). Atualmente, estas aves encontram-se distribuídas por todo o continente americano, desde o Alasca, nos Estados Unidos, até a Terra do Fogo, na Argentina (del Hoyo et al. 2017b). Evolutivamente, o grupo pode ser dividido em nove clados: *Bees, Brilliants, Coquettes, Emeralds*, *Hermits, Mangoes, Mountain Gems, Patagona* e *Topazes*. Estes clados representam conjuntos de espécies agrupados de acordo com suas regiões de origem e distribuição geográfica (Bleiweiss 1998, McGuire et al. 2014). A alta diversidade de espécies (Gill and Donsker 2014) e linhagens de beija-flores (McGuire et al. 2014) também se reflete na alta diversidade de características morfológicas dentro do grupo (del Hoyo et al. 2017b). Uma das possíveis causas desta alta diversidade morfológica é resultante da forte dependência que estas aves possuem em relação às suas fontes de néctar (Stiles 1981). É sugerido que esta dependência tenha gerado bicos com comprimento e curvatura diversificados, que tendem a estar associados ao formato da corola das plantas que visitam (Temeles et al. 2002a, Temeles and Kress 2003, del Hoyo et al. 2017b).

Beija-flores são os principais vertebrados polinizadores de angiospermas nas Américas, visitando mais de 100 famílias e 1,300 espécies de plantas (Arizmendi and

Rodríguez-Flores 2012). As famílias com maior número de espécies polinizadas por beija-flores são, nessa ordem: Fabaceae, Bromeliaceae, Rubiaceae, Gesneriaceae e Lamiaceae (Arizmendi and Rodríguez-Flores 2012). O elevado número de espécies dependentes de beija-flores para a sua polinização destaca a importância do grupo na manutenção deste essencial processo ecossistêmico, principalmente no Neotrópico (Bawa 1990). As interações realizadas entre beija-flores e plantas são as mais especializadas das interações entre aves e flores no mundo (Stiles 1981, Fleming and Muchhala 2008, Zanata et al. 2017). Esta especialização está associada tanto à especialização morfológica existente entre as espécies que interagem, as quais tendem a possuir elevado ajuste morfológico (Stiles 1981, Santamaría and Rodríguez-Gironés 2007, Fleming and Muchhala 2008), quanto à especialização das interações ao nível de comunidade, onde prevalece uma baixa sobreposição de interações entre as espécies (Zanata et al. 2017). Devido à alta diversidade de espécies (Gill and Donsker 2014), história evolutiva bem resolvida (McGuire et al. 2014), ampla diversidade morfológica (del Hoyo et al. 2017b), importância na polinização das angiospermas (Bawa 1990, Arizmendi and Rodríguez-Flores 2012) e elevado número de estudos descrevendo suas interações com seus recursos florais (Martín González et al. 2015), os beija-flores são um interessante modelo de estudo para a Ecologia filogenética e funcional das interações entre animais e plantas (Maruyama et al. 2014, Vizentin-Bugoni et al. 2014a, Martín González et al. 2015), a qual é a linha de pesquisa explorada nesta tese.

Dentre as 345 espécies de beija-flores existentes (Gill and Donsker 2014), 37 (11%) encontram-se globalmente sob alguma categoria de ameaça à extinção e duas são consideradas extintas: *Chlorostilbon bracei* (Lawrence, 1877) e *Chlorostilbon elegans* (Gould, 1860) (IUCN 2017). Embora a Biologia da Conservação tenda a focar na extinção

das espécies, há mais de 40 anos chamou-se a atenção para outro tipo de extinção que pode ser desencadeado pela extinção das espécies: a extinção das interações entre animais e plantas (Janzen 1974). Tendo essa questão como problema norteador, investigamos a vulnerabilidade das interações raras entre beija-flores e suas fontes de néctar (Capítulo 1), uma vez que a raridade tende a ser uma condição que aumenta as chances de extinção, tanto das espécies, quanto das interações (Rabinowitz 1981, IUCN 2017). Esta raridade também foi investigada ao nível da história evolutiva e das características morfológicas dos beija-flores (Isaac et al. 2007), a qual está refletida na baixa redundância das espécies evolutiva e funcionalmente raras. Usando um conjunto de dados composto por 74 redes de interação entre beija-flores e plantas distribuídas pelo continente americano (Martín González et al. 2015), testamos se as espécies de beija-flores pertencentes a linhagens evolutivas raras e com morfologias únicas tendem a ser os polinizadores exclusivos de certas espécies de plantas. Neste sentido, a convergência da raridade evolutiva, morfológica e das interações pode sinalizar o nível de vulnerabilidade das interações não-redundantes que ocorrem no sistema de polinização entre beija-flores e plantas (Capítulo 1).

Além da raridade das interações, nós também avaliamos quais eram as características evolutivas e morfológicas das espécies-chave de beija-flor nas redes de interação (Capítulo 2). Espécies-chave são aquelas que contribuem desproporcionalmente para a manutenção da estrutura do sistema (Paine 1969) e, nesse sentido, evitam a ocorrência da extinção das interações entre as espécies (Janzen 1974). E finalmente, após determinar quais são as características evolutivas e morfológicas das espécies que desempenham as interações raras e das espécies-chave no sistema de polinização entre beija-flores e plantas, testamos quais características estão associadas à vulnerabilidade à

extinção em 341 espécies de beija-flores (Capítulo 3). Considerando os resultados obtidos nos três capítulos desta tese, construímos um panorama da vulnerabilidade das interações entre beija-flores e plantas, assim como das espécies de beija-flores. A síntese de tal panorama encontra-se na sessão de Conclusão Geral desta tese.

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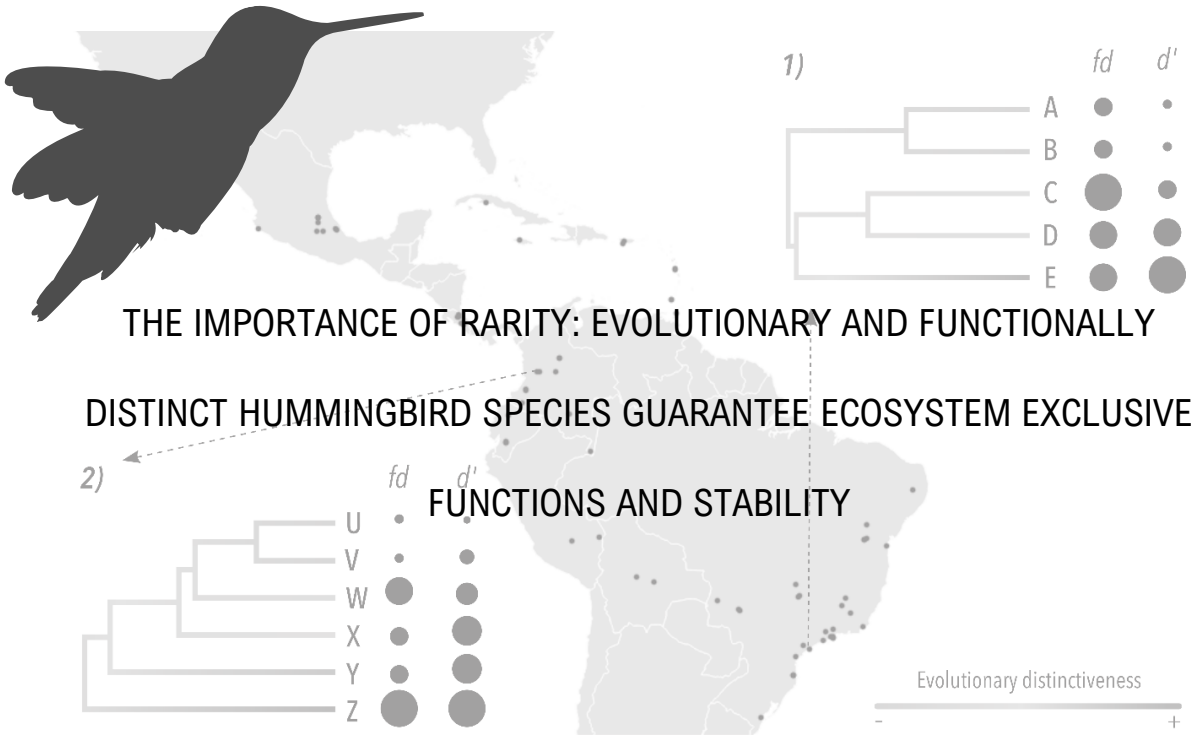
CHAPTER 1



THE IMPORTANCE OF RARITY: EVOLUTIONARY AND FUNCTIONALLY DISTINCT HUMMINGBIRD SPECIES GUARANTEE ECOSYSTEM EXCLUSIVE FUNCTIONS AND STABILITY

Chapter formatted according to the requirements of *Proceedings of the Royal Society B: Biological Sciences*

The importance of rarity: evolutionary and functionally distinct hummingbird species guarantee ecosystem exclusive functions and stability

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Most species are rare within tropical communities. This rarity, or distinctiveness, can be measured at different dimensions of a species, like its evolutionary history, functional traits, trophic interactions and local abundances. However, the importance of rare species for ecosystem functioning and stability is still unclear. Our aim was to detect the contribution of evolutionary and functionally distinct species to the functioning and stability of 74 plant-hummingbird pollination networks across a continental scale, ranging from 38° N to 31° S. We show that evolutionary and functionally distinct hummingbird species tend to perform the most exclusive interactions with their nectar resources, which are also those that prevent secondary extinctions. This result provides evidence for the

importance of evolutionary and functional distinct species in conserving ecosystem exclusive functions and stability.

Keywords: originality, interaction networks, Neotropics, plant-animal interactions, rare, uniqueness

1. INTRODUCTION

Understanding the contribution of different species to ecosystem functioning and stability is urgent under the current high rates of anthropogenic species extinctions (Barnosky et al. 2011). Extinction tends to be associated with species rarity, which may be a consequence of ecological and evolutionary processes (Rabinowitz 1981). Most species are rare within tropical communities (Preston 1948, Chase 2013) and this rarity, or distinctiveness, can be measured at different dimensions of a species (Pavoine et al. 2017), like its evolutionary history (Isaac et al. 2007), functional traits (Violle et al. 2017), trophic interactions (Blüthgen et al. 2006) and local abundances (Preston 1948, Violle et al. 2017). Species with a high level of generalization in trophic interactions and that are locally abundant have been proposed to be keystone species (Olesen et al. 2002, Martín González et al. 2010). However, locally rare species may also perform key functions, disproportionately contributing to ecosystem stability (Lyons et al. 2005, Bracken and Low 2012). The disproportional contribution of rare species indicates a possible ecosystem fragility, since rare species tend to be more vulnerable to extinction, generally being the first to become extinct (Pimm et al. 1988, Purvis et al. 2000b), and have a lower functional redundancy, generally being functionally irreplaceable (Mouillot et al. 2013). Because of their importance, vulnerability and irreplaceability, rare species, evolutionary lineages and

functions may be considered priorities for conservation (Prendergast et al. 1993, Jetz et al. 2014, Hidasi-Neto et al. 2015).

Despite of major importance, few studies have explored the contribution of rare species to ecosystem functioning and stability (Violle et al. 2017). At a local scale, species having the most distinct morphologies tend to perform the most exclusive interactions in plant-insect pollination networks in agricultural landscapes in New Zealand (Coux et al. 2016), as well as in mutualistic networks of plants and hummingbirds (Dalsgaard et al. 2008) and frugivorous birds in the Neotropics (Dehling et al. 2016a). The positive relation between functional and interaction distinctiveness was also detected in mutualistic networks of frugivorous birds at a continental scale (Pigot et al. 2016). Also, evolutionary and functionally distinct species tend to be the rarest species within the community, having the lowest abundances (Mouillot et al. 2013, Pigot et al. 2016).

Hummingbirds (Aves: Trochilidae) tend to be the most specialized nectar-feeding birds in the world (Stiles 1981, Fleming and Muchhala 2008, Zanata et al. 2017), being widely distributed across the Americas (del Hoyo et al. 2017a). These birds are the major vertebrate pollinators of angiosperms, visiting more than 1,300 plant species and performing an essential role in plant reproduction (Arizmendi and Rodríguez-Flores 2012). Extant hummingbirds are a monophyletic group that originated approximately 22 million years ago (McGuire et al. 2014), consisting of nine major evolutionary clades with approximately 345 species (Gill and Donsker 2014, McGuire et al. 2014). Species functional traits characterizing this group are highly diverse and extreme. For example, body mass can vary between 1.6 g in *Mellisuga helenae*, the smallest bird of the world, to 23.0 g in *Patagona gigas* (del Hoyo et al. 2017a). Also, bill morphology are highly diversified in lengths and curvatures, including the occurrence of extreme morphologies

like the highly long bill of *Ensifera ensifera* and the extremely curved bill of the genus *Eutoxeres* (del Hoyo et al. 2017a). These functional traits are thought to be adaptations to fit the morphology and nectar production of their floral resources (Snow and Snow 1972, Temeles et al. 2002b, Dalsgaard et al. 2009).

The aim of this study was to detect the contribution of evolutionary and functionally distinct species to functioning and stability of 74 plant-hummingbird pollination networks, spanning over a large latitudinal range. Since distinct species may perform unique functions in the ecosystem (Lyons et al. 2005, Coux et al. 2016, Dehling et al. 2016a, Pigot et al. 2016), we expected a positive relation between evolutionary and functional distinctiveness of hummingbirds and their trophic interaction distinctiveness. As species interaction frequencies tends to be related to their local abundances (Vizentin-Bugoni et al. 2014b), and evolutionary and functionally distinct species tend to be rare within communities (Mouillot et al. 2013, Pigot et al. 2016), we also expected a positive relation between evolutionary and functional distinctiveness of hummingbirds and their interaction frequencies with nectar resources. Finally, as distinct species tend to perform non-redudant interactions (Dehling et al. 2016b, Pigot et al. 2016), we expected a higher contribution of these species to network robustness to secondary extinctions.

2. MATERIAL AND METHODS

2.1 PLANT-HUMMINGBIRD POLLINATION NETWORKS

To describe the trophic interactions of hummingbirds with their nectar resources at the community-level, we used 74 published and unpublished plant-hummingbird pollination networks sampled along a large latitudinal range at the Americas (38° N to 31° S, Fig. 1, geographical coordinates of each network can be found in Appendix S1). If the study

followed a different taxonomy than Gill & Donsker (2014) for hummingbirds and the Plant List (2013) for plants, we have changed species nomenclature according to these taxonomic proposals. In total, our database describes interaction frequencies between 158 hummingbird and 980 plant species. Hummingbird species richness in each network ranged from two to 15 species, whereas plant species richness ranged from two to 65 species (species richness of each network can be found in Appendix S1).

2.2. CONTRIBUTION OF DISTINCT SPECIES TO ECOSYSTEM FUNCTIONING

To assess the contribution of evolutionary and functionally distinct species to ecosystem functioning, we tested the relation between the different dimensions of species distinctiveness. The distinctiveness measurements of each species were always extracted within each network. Therefore, if a species occured in more than one network, it has more than one evolutionary, functional, interaction distinctiveness and interaction frequency values. In total, our data comprises 527 species occurrences among all networks.

Evolutionary distinctiveness (ED) of each species was measured by the fair proportion index (Isaac et al. 2007), applying the *evol.distinct* function from 'picante' 1.6-2 package in R (Kembel et al. 2010). This index classifies each species by their evolutionary originality through a weighted sum of the branch lengths, from the root to the tip of each species in a time-calibrated phylogeny. The weighting is done by dividing the branch length of each node by the number of species descending from that node. Therefore, greater values of evolutionary distinctiveness characterize species-poor clades within the community, representing rarer evolutionary lineages (Isaac et al. 2007). Thirteen hummingbird species of our database (8%) were not included in the most

comprehensive time-calibrated phylogeny (McGuire et al. 2014). We included these missing species using the phylogeny proposed by McGuire et al. (2014) as a backbone tree (descriptions about the inclusion methods can be found in the Appendix S2). To deal with the phylogenetic uncertainty associated with inclusion of the missing species, we have generated 1,000 hypothetical phylogenies. The new phylogenies were built in the SUNPLIN software (Martins et al. 2013). As a sensitivity analysis, we evaluated the effect of phylogenetic uncertainty in the results of model selection by repeating all analysis described below 1,000 times, using each one of the 1,000 hypothetical phylogenies by time to calculate the evolutionary distinctiveness of each species.

To measure the functional distinctiveness (FD) of each species, we chose three functional traits of hummingbirds that are known to influence their interactions with nectar resources: wing chord, bill length and bill curvature (Snow and Snow 1972, Temeles et al. 2002b, Dalsgaard et al. 2009) (measurements details can be found in the Appendix S3). Functional distinctiveness measurements were also done using the fair proportion index (Isaac et al. 2007), applying the *evol.distinct* function from 'picante' 1.6-2 package in R (Kembel et al. 2010). This is the same index used to measure the evolutionary distinctiveness described above. However, when measuring functional distinctiveness, instead of using a phylogenetic tree, we use a functional dendrogram. This dendrogram was built through a hierarchical clustering analysis, using UPGMA methods with a Euclidian distance matrix of the standardized functional traits, zero mean and unit variance. As for evolutionary distinctiveness, this index classifies each species by their originality by a weighted sum of the branch lengths from the root to the tip of each species in the functional dendrogram. Thus, greater values of functional distinctiveness represent more unique morphologies within the community (Isaac et al. 2007, Hidasi-Neto et al. 2015).

Since evolutionary closely related species may have a greater trait similarity than unrelated species (Münkemüller et al. 2012), we have tested the correlation between evolutionary and functional distinctiveness prior to analyses. As the correlation between these indices were low (r = 0.38, p < 0.05), both dimensions of distinctiveness were considered separately in the analyses. Distribution of functional distinctiveness across the evolutionary history of hummingbirds can be found in Fig. S3 in Appendix S4.

Interaction distinctiveness (*d'*) of hummingbirds in each network was measured by the *d'* index (Blüthgen et al. 2006), applying the *specieslevel* function from 'bipartite' 2.08 package in R (Dormann 2011). This index describes the degree of interaction specialization at the species-level, varying from 0 (generalist) to 1 (specialist) and detecting how exclusive are the interactions performed by a species. To measure the interaction distinctivennes, the index evaluates the deviation of pairwise interaction frequencies in relation to a null model that assumes that the resources are visited in proportion to their availability, which is described by the total species interaction frequencies. Then, greater values of *d'* detect hummingbird species visiting plant species that are rarely visited by other hummingbirds (Blüthgen et al. 2006).

The interaction frequency of hummingbirds with their nectar resources were described by the number of times a given hummingbird species has been observed visiting a given plant species during focal observations. As we do not have independent measures of abundance, we used interaction frequencies as a proxy for hummingbird local abundances (Vizentin-Bugoni et al. 2014b, 2016). To allow comparisons between different networks, we have calculated the relative total interaction frequency of each hummingbird species, which were $\log_{10}$ transformed to achieve normality.

To evaluate the contribution of evolutionary and functionally distinct species to ecosystem functioning, we tested the relation between species interaction distinctiveness and their evolutionary and functional distinctiveness using linear mixed models. In these models, interaction distinctiveness was treated as a response variable, evolutionary and functional distinctiveness as fixed predictor variables and species and networks' identities as random predictor variables. We have used mixed models because some species occurred in more than one network and geographically closer networks may be non-independent observations. The models were built using the *lmer* function from 'lme4' 1.1-13 package in R (Bates et al. 2015). The variance of random predictor variables in the best model were: $\sigma^2_{species}$=0.01 and $\sigma^2_{networks}$ = 0.02. To determine the most important variables predicting interaction distinctiveness of each species, we have performed a model selection, applying the *dredge* function from 'MuMIn' 1.15.6 package in R (Barton 2016). Model selection was done by considering the best model as the one with the lowest value of delta Akaike Information Criterion (ΔAIC) and the highest value of Akaike weights (ωAIC), which represent the probability of a given model to be the best model (Burnham and Anderson 2002). The variance explained by the fixed and random predictor variables of the best model was calculated by the conditional R^2 ($R^2_{GLMM(c)}$), while the variance explained by the fixed effect only was calculated by the marginal R^2 ($R^2_{GLMM(m)}$) (Nakagawa and Schielzeth 2013). Calculations were done by applying the *sem.model.fits* function from the 'piecewiseSEM' 1.2.1 package in R (Lefcheck 2015).

2.3 CONTRIBUTION OF DISTINCT SPECIES TO ECOSYSTEM STABILITY

To test the influence of evolutionary and functionally distinct species in ecosystem stability, we evaluated network fragility to local species extirpation, through the relation

between species interaction frequencies and their evolutionary and functional distinctiveness through linear mixed models. In these models, interaction frequency was treated as response variable, evolutionary and functional distinctiveness as fixed predictor variables and species and networks' identities as random predictor variables. As previously described, we have used mixed models because of the non-independency that may be present in our data. Model building and selection were done with the same methods described above.

We also evaluated the influence of distinct species to ecosystem stability through the comparison of the values of network robustness to secondary extinctions under four scenarios of species extinctions. Robustness was measured using the *robustness* function from 'bipartite' 2.08 package in R (Dormann et al. 2009). The robustness index varies from 0 (fragile) to 1 (robust) by measuring the area below the co-extinction curve. This curve describes the proportion of plant species in the network that were extinct, which means, plant species that lost all hummingbird pollinators, along the sequential removal of hummingbird species. Lower values of robustness indicate that network stability is highly sensitive to hummingbird removals due to non-redundant interactions performed by the hummingbirds in the pollination networks (Memmott et al. 2004).

We evaluated four scenarios of species removals: (1) descending order of evolutionary distinctiveness values of each hummingbird occurring in the network, that is, removing the more to the least evolutionary distinct species; (2) descending order of functional distinctiveness values, that is, removing the more to the least functional distinct species; (3) ascending order of species interaction frequency, that is, removing the species that perform less to the most interactions; and (4) randomly, according to 1,000 randomizations of random species removals. In the first two scenarios, we can detect the

contribution of evolutionary and functionally distinct species to network stability, where low values of robustness indicate that distinct species strongly contributes to ecosystem stability. In the third scenario, we can detect the contribution of species observed interacting less, where low values of robustness indicate that species with few interactions strongly contributes to ecosystem stability. And finally, in the last scenario, we can detect the robustness values obtained under the absence of the biological effects described above (Gotelli and Graves 1996). Robustness values of each network obtained under the different scenarios of hummingbird removals can be found in Fig. S4 in Appendix S4. Comparisons of these values were done using Kruskal-Wallis test and a post-hoc Dunn's multiple comparison test with Bonferroni adjustment methods.

3. RESULTS

We found that evolutionary and functional distinctiveness of hummingbird species predict the distinctiveness of their trophic interactions with nectar resources, at a continental scale (best model: d' = 0.04*ED + 0.03*FD, $R^2_{GLMM(c)}$ = 0.42, $R^2_{GLMM(m)}$ = 0.07; Table 1, Fig. 1). This positive relation was also detected when we repeated the analysis using 1,000 different phylogenetic hypotheses, demonstrating that our results were not affected by the phylogenetic uncertainty of a few missing species (Table 1).

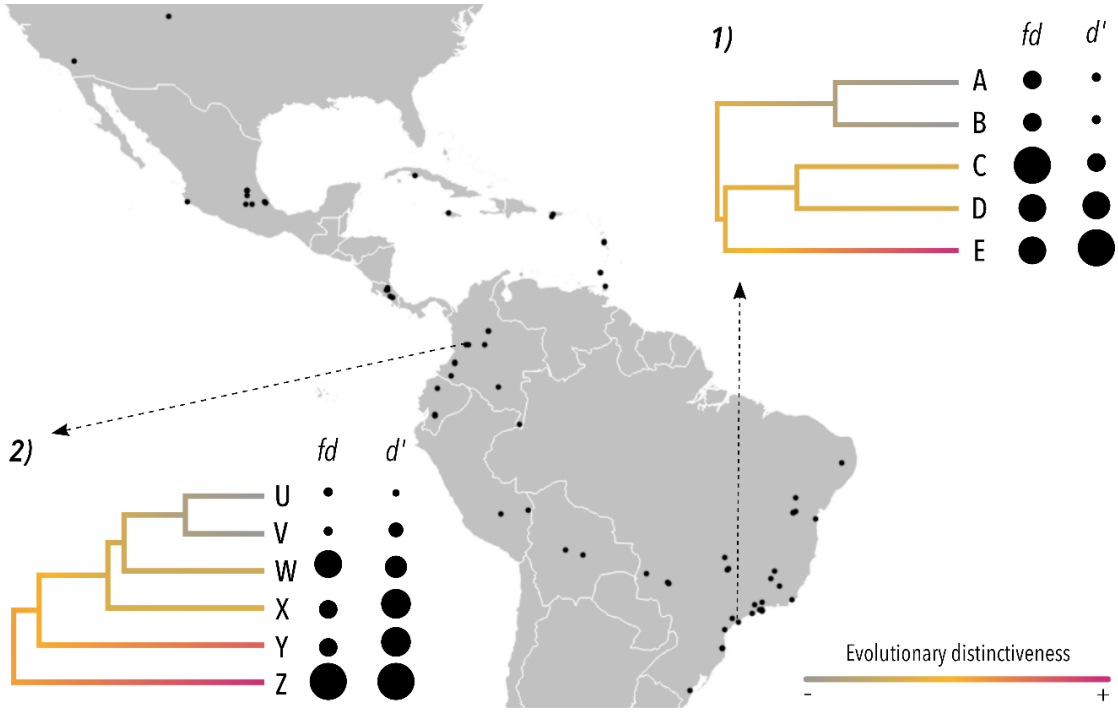

Fig. 1 – Geographical distribution of 74 pollination networks describing the interaction frequency of hummingbird species with their nectar resources. Two networks, representing local hummingbird communities, are highlighted in the figure. These networks illustrate that evolutionary and functionally distinct species tend to perform distinct interactions. The degree of evolutionary distinctiveness of each species is shown by the colours of the phylogenetic trees. The degree of functional (fd) and interaction distinctiveness (d') of each species is represented by the size of circles next to the phylogenies. Hummingbird species occurring in each network: **1)** A – *Hylocharis cyanus*, B – *Thalurania glaucopis*, C – *Phaethornis eurynome*, D – *Rhamphodon naevius*, E – *Florisuga fusca*. **2)** U – *Amazilia tzacatl*, V – *Amazilia saucerottei*, W – *Chlorostilbon mellisugus*, X – *Heliomaster longirostris*, Y – *Anthracothorax nigricollis*, Z – *Phaethornis guy*.

No relation was detected between frequency of interaction and evolutionary and functional distinctiveness of hummingbird species (Table 1). This result was either not affected by the phylogenetic uncertainty (Table S3). Although no differences were detected among the relative frequency of interaction of hummingbird clades after Bonferroni adjustments (K = 16.74, p = 0.02, Fig. S5 in Appendix S4), some patterns at the clade-level were observed: Hermits and Topazes with the highest evolutionary

distinctiveness values had low relative frequencies, while some Brilliants with the highest functional distinctiveness had low relative frequencies (Fig. 2).

Table 1 – Evolutionary and functionally distinct species tend to perform distinct interactions but are independently associated with their interaction frequencies with nectar resources. As a sensitivity analysis for phylogenetic uncertainty, the relations between variables were tested 1,000 times, with evolutionary distinctiveness values obtained by using one of the 1,000 hypothetical phylogenies by time in each model selection. Described are range values of delta Akaike Information Criteria (ΔAIC) and Akaike weights (ωAIC) of these 1,000 model selections. The best model of each response variable is highlighted in bold.

	Interaction distinctiveness		*Interaction frequencies*	
	ΔAIC	**ωAIC**	**ΔAIC**	**ωAIC**
ED + FD	**0.00 – 0.00**	**0.93 – 0.95**	3.66 – 3.83	0.07 – 0.08
FD	5.31 – 6.32	0.04 – 0.06	2.03 – 2.03	0.18 – 0.19
ED	11.34 – 12.28	0.00 – 0.01	1.64 – 1.81	0.21 – 0.22
Null model	23.85 – 24.86	0.00 – 0.00	**0.00 – 0.00**	**0.51 – 0.52**

ED – evolutionary distinctiveness; FD – functional distinctiveness

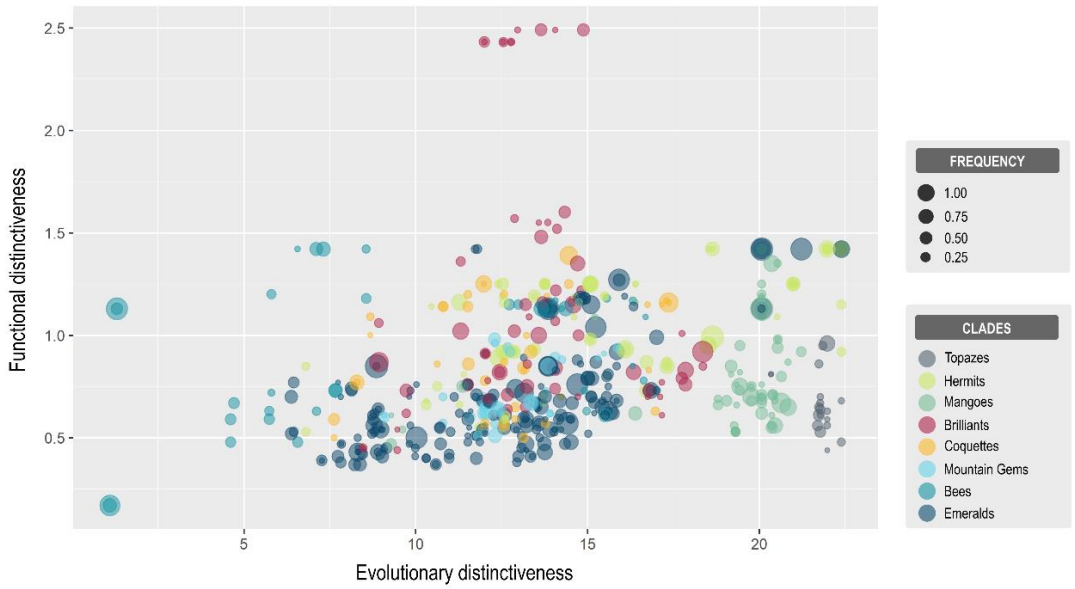

Fig. 2 – Evolutionary and functionally distinct species are independently associated with their interaction frequencies with nectar resources, but Hermits and Topazes, clades with the highest evolutionary distinctiveness, and Brilliants, clade with the highest functional distinctiveness, tend to have low relative interaction frequencies. Circles sizes represent the frequency of interaction of each species in 74 plant-hummingbird networks distributed across the Americas, totalizing 527 species occurrences of 158 hummingbird species. Circle colours represent different evolutionary clades, following McGuire *et al*. (2014).

Under different scenarios of hummingbird species removals, we found that evolutionary and functionally distinct species contributed to pollination networks stability more than species interacting less. Moreover, both scenarios were different from a random removal scenario, reinforcing the existence of a biological effect under the distinctiveness and frequency of interaction removal scenarios (Fig. 3).

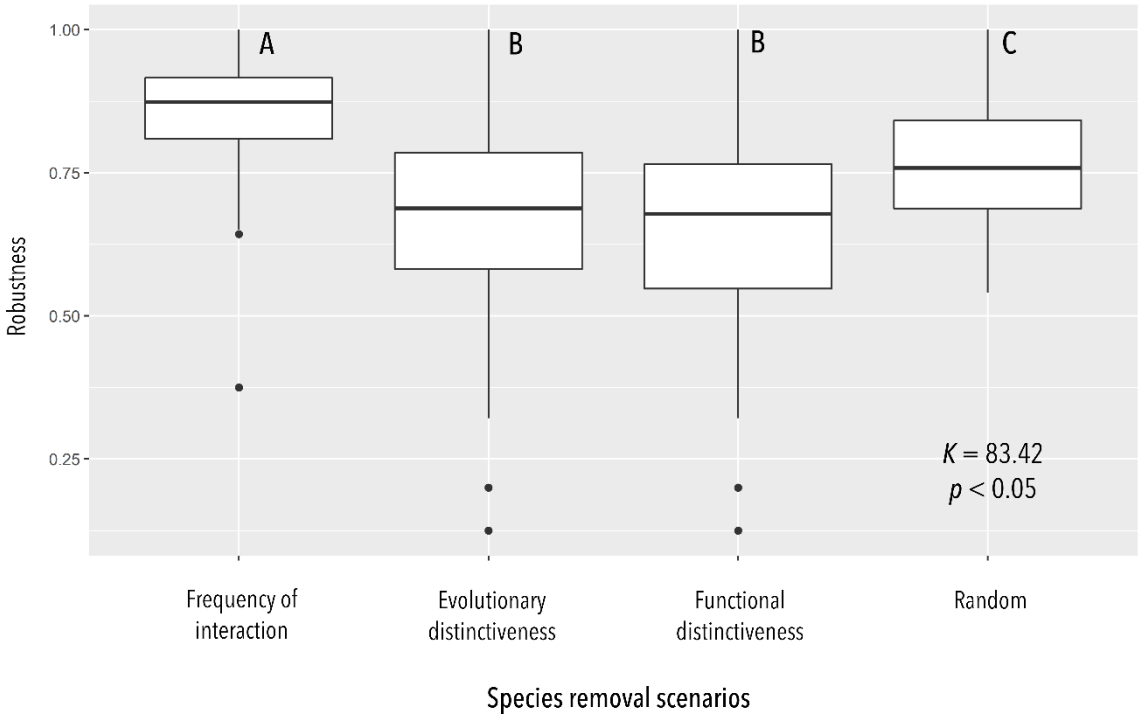

Fig. 3 – Evolutionary and functionally distinct species contributed to pollination networks stability more than species interacting less. Boxplots of the robustness values obtained under four scenarios of hummingbird species removals in 74 pollination networks. Comparisons were done through Kruskal-Wallis test and a post-hoc Dunn's multiple comparison test with Bonferroni adjustment methods.

4. DISCUSSION

We found that hummingbird species belonging to the rarest evolutionary lineages and with the most unique functional traits within the community tend to perform the most exclusive interactions with their nectar resources, as expected. Our findings reinforce the importance of functionally distinctive species performing perform exclusive interactions

in mutualistic networks (Coux et al. 2016, Dehling et al. 2016a, Pigot et al. 2016). Also, this is the first evidence of the importance of evolutionary distinct species performing exclusive interactions. Although evolutionary and functional distinctiveness may be correlated (Münkemüller et al. 2012), the relations that we detected in our study did not occur because of the possible correlation between species evolutionary and functional distinctiveness, since in our study these correlation was low. Thus, this result supports the evidence that both evolutionary and functional distinctiveness dimensions may affect hummingbird functions in the ecosystems.

The convergence found between evolutionary, functional and interaction distinctiveness exposes a vulnerability in hummingbird pollination systems, since exclusive functions are performed by locally evolutionary and functionally non-redundant species (Pavoine et al. 2017). Although in other biological systems evolutionary and functionally distinctive species may be locally rare (Mouillot et al. 2013; Pigot et al. 2016), exclusive functions in hummingbird pollination systems may be buffered against extirpation because more distinct hummingbirds are not those interacting less. The absence of relation between species distinctiveness and their interaction frequencies may be due to the nature of our system, as well as due the use of traits that are related with the pollination service provided by hummingbirds (Snow and Snow 1972, Temeles et al. 2002b, Dalsgaard et al. 2009). Since species in pollination systems have a higher mutual dependency than in other systems (Pocock et al. 2012), exclusive interactions performed by species interacting less that are also evolutionary and functionally distinct species would be extremely vulnerable to local extinctions. This relation would explain why it is harder to find a relation between species distinctiveness and frequency of interaction in pollination systems than in other ecosystem services, like carbon storage performed by

locally rare species (Mouillot et al. 2013) or even in other mutualistic systems, like seed dispersal (Pigot et al. 2016). Another possible source for the permanency of exclusive functions in hummingbird pollination systems is that rare evolutionary lineages are not more prone to extinction than common evolutionary lineages (Zanata et al. *in prep*., Chapter 3 of this thesis).

Despite the absence of relation between evolutionary and functional distinctiveness and interaction frequencies, the patterns found between these variables at the clade-level highlight the vulnerability of interactions performed by some species within clades that have a high degree of evolutionary and functional distinctiveness. For example, we found that some Hermits and Topazes, the most evolutionary distinct clades, tend to interact less than other clades. Moreover, some Brilliants, the most functionally distinct clade, also tend to have low frequencies of interaction with their nectar resources. Brilliants typically have medium-to-large body size and medium-to-long straight bills (Stiles 2008), morphological features that make them the most functionally distinct clade among the hummingbirds, as we found. Besides interacting less with their nectar resources and having rare morphologies, Brilliants also have the smallest geographical range size among the hummingbirds (McGuire et al. 2014). Therefore, Topazes, Hermits and Brilliants could be characterized as ecological outliers (Violle et al. 2017), since they have low interaction frequencies, which may be related with low local abundances (Vizentin-Bugoni et al. 2014b), rare evolutionary lineages and morphologies, and in some cases also small range sizes (McGuire et al. 2014). Thus, our results extend the recommendations about the conservation of most distinct species (Isaac et al. 2007, Cadotte and Davies 2010, Jetz et al. 2014, Hidasi-Neto et al. 2015), since they may could

be more vulnerable to extinction (Pimm et al. 1988, Purvis et al. 2000b), but also perform exclusive functions in the ecosystems.

Besides the contribution of distinct species to ecosystem functioning, we also found that distinct species may contribute to pollination network robustness, by preventing secondary extinctions. Although network studies have shown the higher importance of species with high levels of interaction frequencies for ecosystem stability (Olesen et al. 2002, Martín González et al. 2010), our results demonstrated that the loss of an evolutionary and functionally distinct species may have a greater impact on the maintenance of pollination network stability than the loss of species interacting less, which may be the first to become locally extirpated (Pimm et al. 1988, Vizentin-Bugoni et al. 2014b). Also, these results indicate that interactions performed by evolutionary and functional distinct hummingbirds in pollination networks are less redundant than the interactions performed by species with high interaction frequencies (Memmott et al. 2004). This lower dependence of hummingbird pollination systems on species with lower levels of interaction frequencies and the absence of relation between frequencies and distinctiveness dimensions, as we found, suggest that these patterns of community and interactions organization may increase the stability of this pollination system.

5. CONCLUSION

Our results evidence the importance of evolutionary and functional distinctiveness for ecosystem functioning and stability in plant-hummingbird networks. Species belonging to rare lineages and with rare morphologies within the community are the exclusive pollinators of certain plant species, which are also those preveting secondary extinctions. Our study also suggests that the relation between interaction frequency and

distinctiveness may differ in assemblages where there is a high dependency among species, as in pollination networks. These findings reinforce the importance for the conservation of the most distinct species, since these efforts could have the potential to simultaneously conserve ecosystem unique functions and ecosystem stability.

AUTHORS CONTRIBUTION

TBZ and TSM conceived the ideas, TBZ and TSM performed the analyses. TBZ wrote the first draft of the manuscript, and all authors contributed to revisions.

FUNDING

This study was funded by CAPES Foundation (PDSE scholarship proc. 8105/2014-6), MCTI/CNPQ/UNIVERSAL (proc. 445405/2014-7), the Center for Macroecology, Evolution and Climate (CMEC) and the Danish Council for Independent Research Natural Sciences.

ACKNOWLEDGMENTS

We thank Marcos Carlucci and Guilherme Seger for their suggestions and help with the analyses.

SUPPLEMENTARY MATERIAL

APPENDIX S1 – Plant-hummingbird interaction networks descriptions (available at the "Material Suplementar" section, p. 162).

APPENDIX S2 – Inclusion methods of the species missing in the phylogeny of McGuire et al. (2014) (available at the "Material Suplementar" section, p. 171).

APPENDIX S3 – Morphological traits measurements (available at the "Material Suplementar" section, p. 173).

APPENDIX S4 – Complementary analyses.

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7. SUPPLEMENTARY MATERIAL

APPENDIX S4 – COMPLEMENTARY ANALYSES

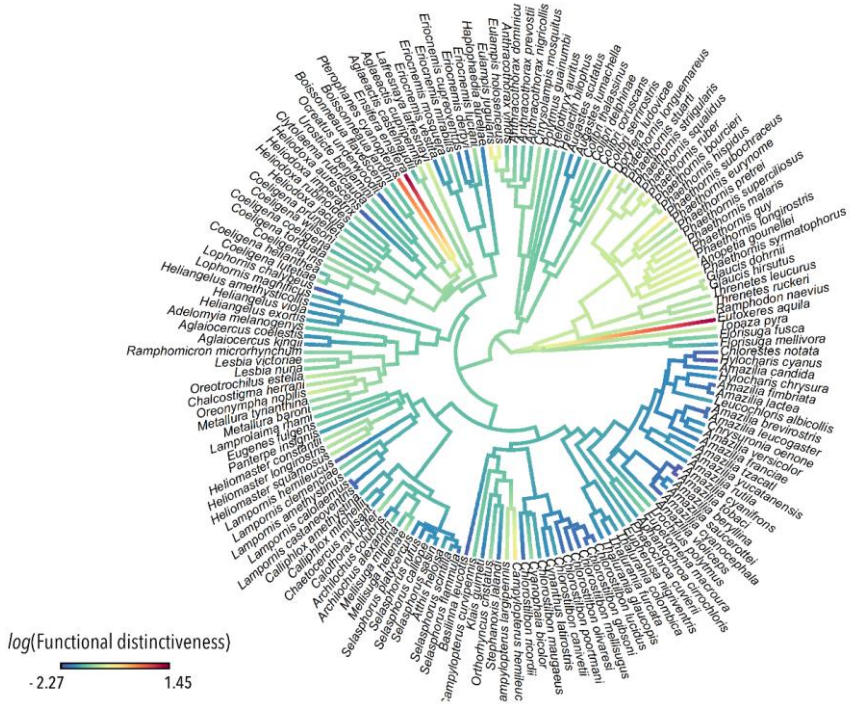


Fig. S3 – Functional distinctiveness distribution across the evolutionary history of 158 hummingbird species. This phylogeny was built using McGuire *et al*. (2014) as a backbone tree, with 13 missing species included as described in the Material and Methods section.

Fig. S4 – Robustness values of each plant-hummingbird pollination network (n = 74) obtained under four scenarios of hummingbird removals: (1) descending order according to evolutionary distinctiveness values of each species occurring in the network, (2) descending order according to functional distinctiveness values, (3) ascending order according to frequency of interaction values, and (4) mean robustness value obtained under 1,000 randomizations of random extinctions of species.

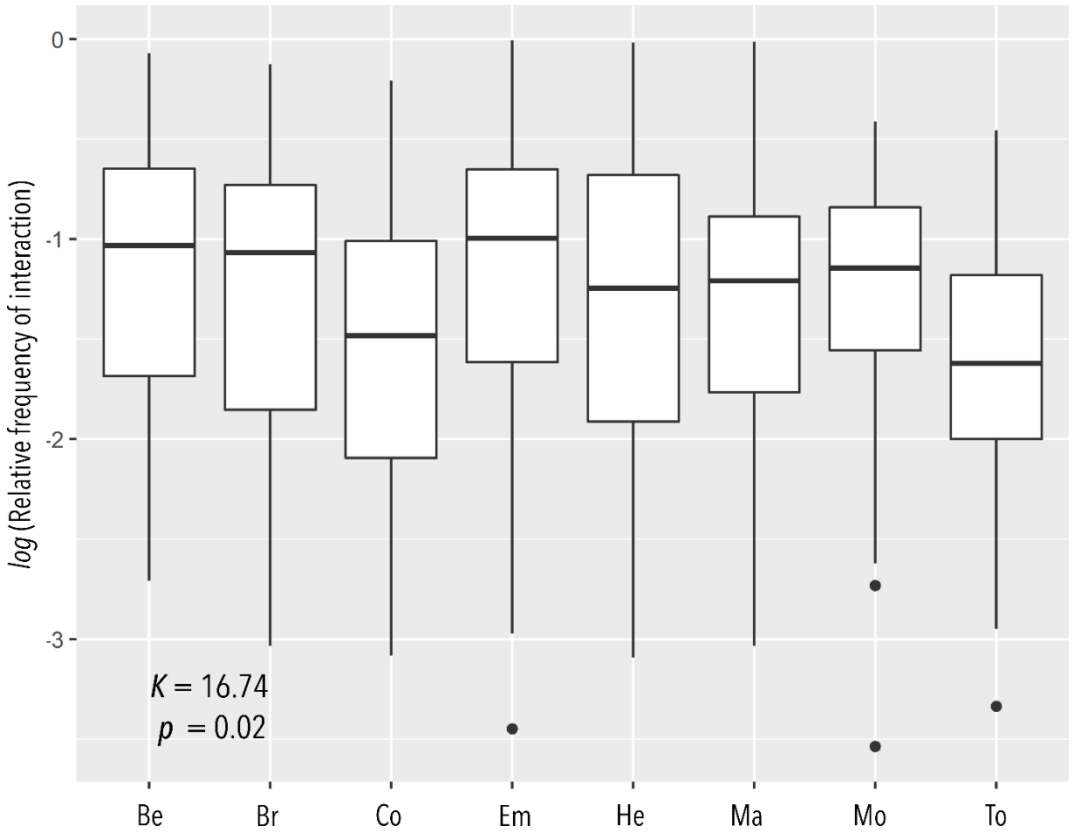
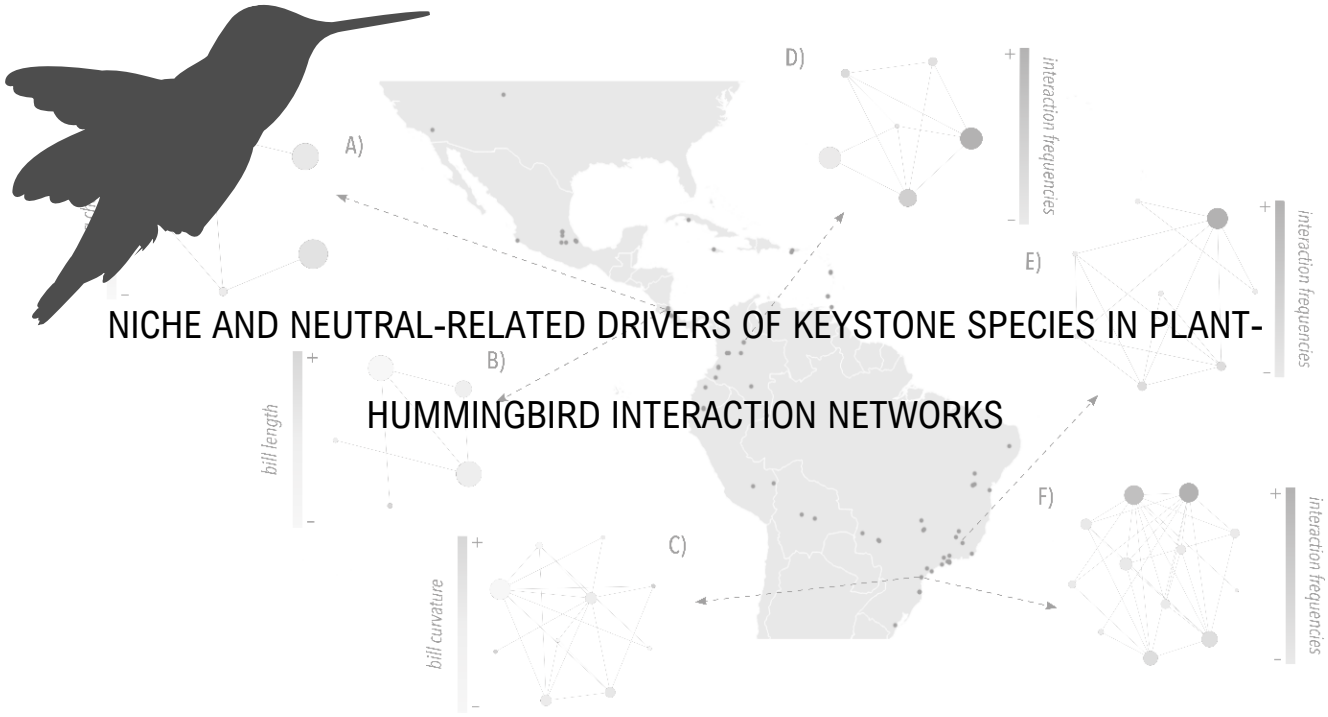


Fig. S5 – Boxplots of the relative local abundances (log_{10} transformed) of different hummingbird clades. Comparisons were done through Kruskal-Wallis test and a post-hoc Dunn's multiple comparison test with Bonferroni adjustment methods. Hummingbird clades: *Be* – Bees; *Br* – Brilliants; *Co* – Coquettes; *Em* – Emeralds; *He* – Hermits; *Ma* – Mangoes; *Mo* – Mountain gems; *To* – Topazes.

CHAPTER 2



NICHE AND NEUTRAL-RELATED DRIVERS OF KEYSTONE SPECIES IN PLANT-HUMMINGBIRD INTERACTION NETWORKS

Chapter formatted according to the requirements of *Oikos*.

Niche and neutral-related drivers of keystone species in plant-hummingbird interaction networks

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The relative importance of species to community structure and stability varies among species, with some being crucial and some being of less importance. Keystone species are those with a disproportionately higher relative importance within the community. Identifying the drivers explaining why a species is a keystone can improve our understanding of the patterns of interactions within communities, and thus, help to predict responses to disturbances. The network approach has proved useful in operationalizing the ecological keystone concept by identifying important species that maintain network structure and stability. However, we have limited knowledge about what characterise keystone species in ecological networks. In this study, we used 74 plant-hummingbird interaction networks to identify the importance of niche and neutral-related drivers in producing hummingbird keystone species. Keystone species were described as those with

higher degree, betweenness and closeness centrality metrics. Niche-related drivers were described by species morphological traits and evolutionary history, whereas neutral effects were estimated by species interaction frequencies. We found that hummingbird species with short and straight bills, large wing chords, higher interaction frequencies and belonging to the evolutionary clades of Bees, Emeralds and Mangoes have higher centrality measures, and thus, may be interpreted as keystone species in plant-hummingbird networks. Our findings highlight the importance of both niche and neutral-related drivers in producing keystone species, as well as the need in developing a conservation policy based on important species, rather than only on rare species, when the goal is to maintain community structure and its associated ecosystem functions and services.

Keywords: centrality, ecological networks, keystone species, neutral drivers, niche drivers, phylogeny, plant-animal interactions.

1. INTRODUCTION

Keystone species are those with a disproportionately higher relative importance within the community (Paine 1969, Power et al. 1996). This disproportional importance is associated with the greater impact to community integrity of losing keystone species when compared to losing other less important species (Dunne et al. 2002, Memmott et al. 2004). Thus, the detection of keystone species is valuable for understanding the organization of ecological communities (Paine 1969, Ebenman and Jonsson 2005), for ecosystem restoration (Palmer et al. 1997, Simberloff 1998) and for identifying target species for conservation purposes (Caro 2010).

Species coexisting in a community and its interactions can be synthesized in interaction networks (Bascompte and Jordano 2007). In the network context, the topological position of each node (ecologically representing species) defines its relative importance to network structure and stability (ecologically representing the community) (Nooy et al. 2005). From the network perspective, keystone species would be nodes with a higher number of interactions and connecting different parts of the network (Jordán 2009, Martín González et al. 2010). As for other approaches, their higher relative importance is associated with the greater impact to network integrity when removing these nodes (Dunne et al. 2002, Memmott et al. 2004, Nooy et al. 2005). In the last decade, the network approach has proved useful in operationalizing the ecological keystone concept by identifying important species maintaining the structure and stability of interaction networks (Dunne et al. 2002, Memmott et al. 2004, Stang et al. 2006, Jordán 2009, Martín González et al. 2010), but we know little about the drivers leading to these keystone species (Sazima et al. 2010, Mello et al. 2013, 2015, Schleuning et al. 2014). Identifying the drivers can improve our understanding of the patterns of interactions within communities (Stang et al. 2006, Mello et al. 2015), and thus, help to predict responses to disturbances (Dunne et al. 2002, Memmott et al. 2004, Brose et al. 2005).

In recent years, studies have shown that both neutral and niche-based processes may affect mutualistic networks (Stang et al. 2006, Dalsgaard et al. 2008, Vizentin-Bugoni et al. 2014a, 2016). Among niche-related drivers, species morphological traits revealed to be an important factor in producing keystone species. For example, in some plant-insect pollination networks, keystone species have smaller nectar holder depth and greater nectar holder width (Stang et al. 2006), while in a seed dispersal network keystone species have larger body mass (Donatti et al. 2011). Additionally, morphological constraints were

also an important factor in predicting the organization of plant-hummingbird pollination networks (Dalsgaard et al. 2008, Maruyama et al. 2014, Vizentin-Bugoni et al. 2014a, 2016). Besides morphology, other niche-related drivers of interactions may determine the occurrence of keystone species in mutualistic networks, such as species dietary specialization (Krishna et al. 2008, Schleuning et al. 2014, Mello et al. 2015), foraging behaviour (Schleuning et al. 2014) and trophic categories (Sazima et al. 2010). Moreover, species evolutionary history can also be a determinant factor affecting species topological position in mutualistic networks (Martín González et al. 2010), with closely related species having similar patterns of interaction (Rezende et al. 2007, Schleuning et al. 2014).

Among neutral drivers, species abundances are considered as a null hypothesis to niche-related drivers, with the patterns of interactions being explained only by the chance of encounters as determined by species abundances (Vázquez et al. 2007). In several networks where a niche-related driver was detected as an important factor in producing keystone species, the effect of species abundances was also detected in determining species centrality (Stang et al. 2006, Krishna et al. 2008, Sazima et al. 2010, Schleuning et al. 2014). This pattern highlights the importance of both neutral and niche-related drivers in producing keystone species in mutualistic networks.

Our aim was to identify the importance of niche and neutral-related drivers for community structure and stability through the analysis of their effects on keystone hummingbird species in a continental dataset of plant-hummingbird pollination networks. Hummingbirds are the major vertebrate pollinators of angiosperms in tropical Americas, visiting more than 1,300 plant species (Arizmendi and Rodríguez-Flores 2012). This great number of plants pollinated by hummingbirds stresses the importance of these birds in maintaining an essential ecosystem process in plant reproduction (Arizmendi and

Rodríguez-Flores 2012). Therefore, the identification of keystone species and their drivers can be useful for ecosystem restoration and conservation purposes (Caro 2010). We tested niche effects through the relation between network topological positions of hummingbird species and their morphological traits and evolutionary history, while neutral effects were tested through the relation with their interaction frequencies. Considering other mutualistic systems (Stang et al. 2006, Sazima et al. 2010, Schleuning et al. 2014), we expected that both niche and neutral drivers affect species topological positions in the interaction networks. Specifically, we expected that hummingbirds with long and straight bills, large wing chords and higher interaction frequencies will be keystone species, since they tend to pollinate a greater number of plant species (Snow and Snow 1972, Temeles et al. 2002b). Moreover, we also expected to find a phylogenetic signal in centrality metrics, since evolutionary history can affect species interaction patterns (Rezende et al. 2007, Mello et al. 2013, Schleuning et al. 2014).

2. MATERIAL AND METHODS

2.1 PLANT-HUMMINGBIRD INTERACTION NETWORKS

We analysed 74 published and unpublished plant-hummingbird interaction networks distributed across a large latitudinal range in the Americas (38°N to 31°S, Fig. 1, geographical coordinates of each network can be found in the Appendix S1). Each network was summarized in an adjacency matrix, with plant species in rows and hummingbird species in columns. These matrices describe the nectar resources visited by the hummingbird community in a given locality. Visits of a hummingbird species to a plant species were represented by 1, while the absence of interaction between a pair of hummingbird and plant species was represented by 0. In total, our dataset describes the

interactions between 158 hummingbird species and 980 plant species, with 527 hummingbird species occurrences among all networks. We followed the taxonomy proposed by Gill and Donsker (2014) for hummingbirds and the Plant List (2013) for plants. Hummingbird species richness in each network ranged from two to 15, whereas plant species richness ranged from two to 65 (species richness of each network can be found in the Appendix S1).

2.2 DETECTING KEYSTONE SPECIES

To detect keystone pollinators in the networks, we used the following binary metrics: degree centrality (DC), betweenness centrality (BC) and closeness centrality (CC). Centrality metrics describe the topological position of each species by quantifying how central or peripheral it is within a network, and therefore, describe the relative importance of each species in maintaining network structure and stability (Nooy et al. 2005). Thus, species with high values of centrality can be classified as keystone species (Power et al. 1996, Martín González et al. 2010).

DC quantifies the number of plant species visited by a focal species (Dormann 2011). Ecologically, higher DC values represent a species with a high level of interaction generalization (Dormann 2011). In the pollination context, this species is classified as a keystone because it pollinates a high proportion of plant species in the community, disproportionately contributing to ecosystem functioning (Power et al. 1996, Dunne et al. 2002, Memmott et al. 2004, Mello et al. 2015). Since DC is correlated with network size, to compare networks with different sizes, we calculated the relative DC (Martín González et al. 2010). This calculation was done by dividing the number of plant species visited by

a focal species by the number of plant species that are available for visitation in the given network (Dormann 2011).

To measure BC and CC, we transformed the two-mode networks of plants and hummingbirds in one-mode networks, with hummingbird species as network nodes. In one-mode networks, a pair of nodes is connected if the pair of hummingbird species visited at least one common plant species in the community (Nooy et al. 2005, Dalsgaard et al. 2008, Martín González et al. 2010). Therefore, these networks represent a niche overlap network among hummingbird species coexisting in a given community (Mello et al. 2015). BC quantifies the number of shortest paths between two species that include the focal species (Nooy et al. 2005, Dormann 2011). Then, species with high values of BC are the most important species to maintain network cohesiveness against compartmentalization (Nooy et al. 2005), being connectors of subnetworks within the network (Martín González et al. 2010). Ecologically, higher BC values represent a species that pollinates plant species from different guilds or compartments (Mello et al. 2015), and therefore, may be classified as keystone species because it contributes to the maintenance of ecosystem structure and stability (Martín González et al. 2010).

CC is the inverse of the mean distance of the focal species to all other species (Dormann 2011). Then, species with high CC values are those with the shortest distances to all other species in the network (Nooy et al. 2005). Ecologically, higher CC values represent a species with a high niche overlap with all other species in the community (Mello et al. 2015). Therefore, this species can be classified as a keystone because it summarizes different functions by pollinating the same plant species that are visited by different hummingbird species in the community (Mello et al. 2015), disproportionately contributing to ecosystem functioning (Martín González et al. 2010). Since BC and CC

values range are correlated with network size (Nooy et al. 2005), to compare networks with different sizes, we standardized the values to sum 1. Centrality measurements were calculated using the "specieslevel" function in the *bipartite* package in R (Dormann 2011, R Core Team 2017).

Species interaction frequencies may affect their topological positions in interaction networks (Vázquez et al. 2007, Sazima et al. 2010) and this relation was also detected in our results (Table 1). Then, to identify species that occupy a more central position than expected by their interaction frequencies, we calculated species z-scores in each network. This calculation was done by the following formula: $\frac{obs - \mu_{exp}}{\sigma_{exp}}$, where *obs* is the observed metric value for a given species, while μ_{exp} and σ_{exp} are the mean and the standard deviation of the expected value under 1,000 randomizations of the observed adjacency matrix. Since we wanted to calculate the expected values according to species interaction frequencies in a given community, in these randomizations we kept constant the sum of the marginal totals, which may be used as a surrogate for species abundances in the community (Vizentin-Bugoni et al. 2014a), as well as the matrix size, which represents the number of plant and hummingbird species in a given community (Patefield 1981). Then, species with z-scores $\geq$ 1.96 were those that occupy a more central position than expected by their interaction frequencies, indicating that a non-neutral driver may be determining the topological position occupied by this species in the interaction network (Vázquez et al. 2007). Randomizations were done using the "nullmodel" function in the *bipartite* package in R (Dormann 2011).

2.3 NICHE-RELATED DRIVERS OF KEYSTONE SPECIES

Niche-related drivers were described by species morphological traits and evolutionary history. We chose three morphological traits of hummingbirds that are known to influence their interactions with nectar resources: bill length, bill curvature and wing chord (Snow and Snow 1972, Temeles et al. 2002b). We obtained these trait measurements from the inspection of 10 adult museum specimens of each species (details about the measurements can be found in the Appendix S2). As the range of species morphological traits may vary among communities, especially in continental scales like our study, before the analyses we standardized the morphological measurements. The standardization was done by dividing each morphological value by the value of the larger species found within a given network.

The evolutionary history of hummingbirds was described based on the most comprehensive time-calibrated phylogeny (McGuire et al. 2014). However, thirteen species of our dataset (8%) were not included in this phylogenetic hypothesis. To overcome this problem, the missing species were included in McGuire et al. (2014) phylogeny (descriptions about the inclusion methods can be found in the Appendix S3). To deal with the phylogenetic uncertainty associated with the inclusion of the missing species, we have generated 1,000 hypothetical phylogenies in the SUNPLIN software (Martins et al. 2013).

2.4 NEUTRAL DRIVER OF KEYSTONE SPECIES

Neutral driver is ideally described by species local abundances (Stang et al. 2006, Vázquez et al. 2007, Sazima et al. 2010). But as we do not have species abundance data for all networks, we used the total frequency of interaction of each species in a network as a

proxy for their local abundances (Vizentin-Bugoni et al. 2014a, 2016). Frequency of interaction describes the number of individuals of a species observed visiting a plant species in a given network. To allow comparisons among networks with different species richness and sampling efforts, we calculated the relative species interaction frequencies. This calculation was done by dividing the number of interactions of each species, by the total number of interactions of all species observed in a given network.

2.5 RELATION BETWEEN KEYSTONE SPECIES AND NEUTRAL AND NICHE-RELATED DRIVERS

To test if the topological positions occupied by hummingbird species can be predicted by neutral and niche-related drivers, we built three generalized mixed models. In each model, the response variables were DC, BC and CC values, respectively, and the fixed predictor variables were bill length, bill curvature, wing chord and interaction frequencies of each hummingbird species. Species and network identity, as well as the biogeographical province (Morrone, 2014) where each network was sampled, were included as random effect predictor variables in the models. We included these variables to consider the non-independency of observations in our data, since some species occurred in more than one network and closer networks, as well as networks occurring in the same biogeographical province, may be more similar than distant networks or occurring in different biogeographical provinces (Zuur et al. 2009). Considering data distribution, generalized mixed models of DC and BC were built using the binomial family and complementary log-log link function, while CC models were built using the Gaussian family, with arcsine transformation of CC values (Zuur et al. 2009). Since we calculated species z-scores to identify species occupying a more central position than expected by their frequency of

interactions, in the models with $BC_{z\text{-scores}}$ and $CC_{z\text{-scores}}$ as the response variables, we excluded species interaction frequencies as a predictor variable. In these models, we tested only the relation between z-scores values and species morphological traits. The remainder model building for $BC_{z\text{-scores}}$ and $CC_{z\text{-scores}}$ followed the methods described above. $BC_{z\text{-scores}}$ and $CC_{z\text{-scores}}$ values were $\log_{10}$ transformed to achieve normality and the relation between the variables was tested through linear mixed models. Since only four observations of $DC_{z\text{-scores}}$ were $\geq$ 1.96, we did not test the relation between $DC_{z\text{-scores}}$ and species morphological traits. Generalized mixed models were built using the "glmer" function, while linear mixed models were built using the "lmer" function in the *lme4* package in R (Bates et al. 2015).

Model selection was performed based on Akaike Information Criteria (AIC_c) corrected for small sample sizes. The model with the lowest AIC_c was identified as the minimum adequate model (MAM). Predictor variable importance ($\Sigma\omega_i$) was calculated through the sum of the Akaike weights (ω) of the subset of models that a given variable was present. Akaike weights describe the weight of evidence of a given model to be the best model among the set of possible models. Then, greater values of $\Sigma\omega_i$ indicate that a given variable has a greater importance in predicting the response variable values than other variables in the models. To estimate the predictor variable importance ($\Sigma\omega_i$) and the averaged coefficients (AVM) among models, we selected a subset of models that represents a cumulative sum of Akaike weights (ω) $\leq$ 0.95 (Burnham and Anderson 2002).

To test if the topological positions occupied by hummingbird species in plant-hummingbird networks can be predicted by their evolutionary history, we estimated the phylogenetic signal in species centrality values. For species occurring in more than one network, and thus having more than one DC, BC and CC values, we estimated the mean

value of these centrality metrics. Phylogenetic signal was tested using the λ statistics, which describes trait evolution across the phylogeny (Freckleton et al. 2002). λ values can vary from 0 to 1, with values close to 0 indicating no phylogenetic signal and values close to 1 indicating the presence of phylogenetic signal under a Brownian motion evolutionary model (Freckleton et al. 2002), which describes a random walk with trait variation being directly proportional to branch length (Felsenstein 1985). The occurrence of a phylogenetic signal indicates a tendency of evolutionary closely related species to be more functionally similar than evolutionary distantly related species (Münkemüller et al. 2012). We chose to use λ statistics because it has a better performance in detecting phylogenetic signal in ecological traits (Münkemüller et al. 2012) and in dealing with suboptimal branch-length information than other indexes (Molina-Venegas and Rodríguez 2017). As described above, we used the phylogenetic hypothesis proposed by McGuire et al. (2014), which did not include all species occurring in our dataset. Then, we have generated 1,000 new phylogenetic hypotheses including the missing species (details about the methods of inclusion can be found at Appendix S3). As a sensitivity analysis, we evaluated the effect of the phylogenetic uncertainty created by the inclusion of the missing species by repeating all analysis described above 1,000 times, using each one of the 1,000 hypothetical phylogenies by time to calculate the phylogenetic signal in DC, BC and CC species values.

3. RESULTS

DC of hummingbirds in plant-hummingbird interaction networks across the Americas ranged from 0.01 to 1.00 (μ = 0.32, σ = 0.25), BC ranged from 0.00 to 1.00 (μ = 0.09, σ = 0.17) and CC ranged from 0.00 to 0.50 (μ = 0.14, σ = 0.09). Correlation between

centrality metrics was low ($\rho_{DC\text{-}BC}$ = –0.17*, $\rho_{DC\text{-}CC}$ = 0.26*, $\rho_{DC\text{-}CC}$ = 0.06, *$p \leq 0.05$). Species centrality values in each network can be found in the Appendix S4.

DC of hummingbird species was predicted by their wing chord (WC) and interaction frequencies (IF) (DC = 1.95*WC + 1.51*IF – 3.27), BC was predicted by their bill curvature (BCu) and interaction frequencies (BC = –1.52*BCu + 3.94*IF – 3.96), while CC was predicted by their bill length (BL) and interaction frequencies (CC = – 0.02*BL + 0.09*IF + 0.46) (Table 1, Fig. 1).

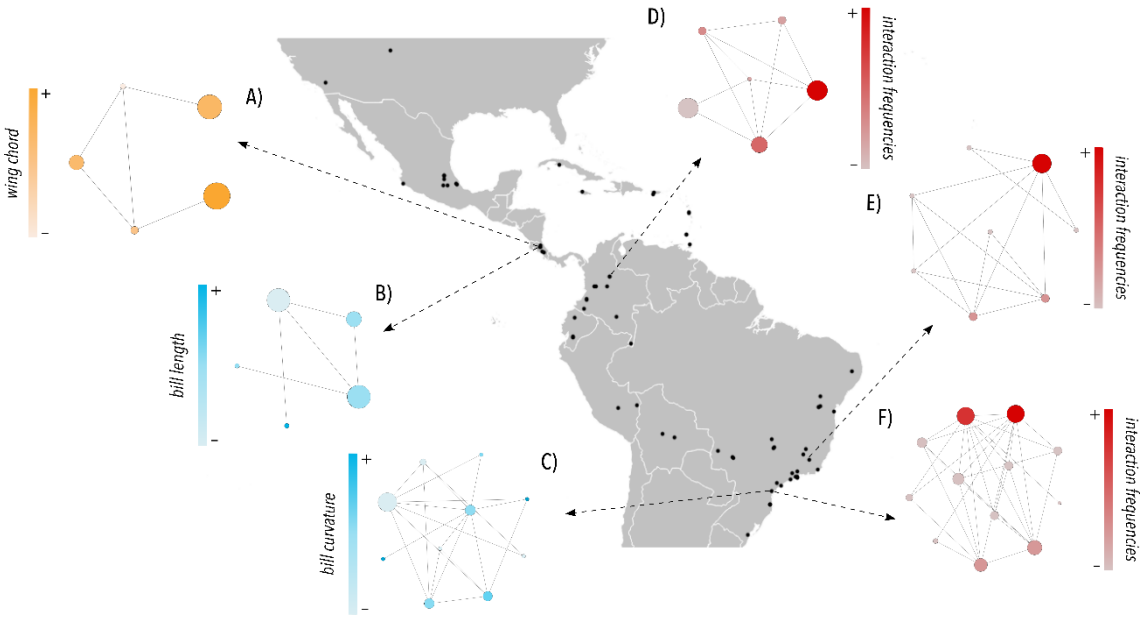

Fig. 1 – Geographical distribution of 74 plant-hummingbird interaction networks across the Americas. Six one-mode networks of hummingbird species are highlighted in the figure. Hummingbird species with short and straight bills, large wing chords and higher interaction frequencies are keystone species in plant-hummingbird networks. Keystone species are described by centrality level, which is represented by the size of nodes in the networks. Colour intensity describes the morphological features and interaction frequencies of hummingbirds. **A)** degree centrality and wing chord (network n. 74 in the database, Appendix S1), **B)** closeness centrality and bill length (network n. 74), **C)** betweenness centrality and bill curvature (network n. 43), **D)** degree centrality and interaction frequencies (network n. 63), **E)** betweenness centrality and interaction frequencies (network n. 1), **F)** closeness centrality and interaction frequencies (network n. 56).

Table 1 – Models predicting the relation between niche and neutral-related drivers and the topological positions of hummingbird species in plant-hummingbird interaction networks across the Americas. A dash indicates that the variable was absent in the minimum adequate model (MAM).

	DC			*BC*			*CC*		
	$\Sigma\omega_i$	AVM	MAM	$\Sigma\omega_i$	AVM	MAM	$\Sigma\omega_i$	AVM	MAM
Bill length	0.28	-0.20	–	0.24	1.50	–	0.65	-0.02	-0.02
Bill curvature	0.27	0.10	–	0.65	-1.71	-1.52	0.22	0.01	–
Wing chord	1.00	1.98	1.95	0.33	-1.58	–	0.22	0.01	–
Int. frequencies	1.00	1.51	1.51	1.00	3.86	3.94	1.00	0.09	0.09

AVM – conditional averaged coefficients; BC – betweenness centrality; CC – closeness centrality; DC – degree centrality; $\Sigma\omega_i$ – predictor variable importance described by the sum of Akaike weights (ω) of all models that a given variable was present; MAM – standardized coefficients of the minimum adequate model, which was the model with the lowest AIC_c. AVM and $\Sigma\omega_i$ were calculated with a subset of all models that represents a cumulative sum of Akaike weights (ω) $\leq$ 0.95.

Considering the null expectation given by the contribution of species interaction frequencies to centrality metrics, for DC only four observations were higher than expected by interaction frequencies. But, BC and CC were less described by hummingbirds' interaction frequencies, with 57 (11%) and 125 (24%) observations of higher BC and CC values than expected by their interaction frequencies. Also, according to $BC_{z\text{-scores}}$ values, topological positions occupied by hummingbird species that were more central than expected by their interaction frequencies were predicted by their bill length (BL) ($BC_{z\text{-scores}}$ = – 0.92*BL + 2.26). However, none morphological trait predicted $CC_{z\text{-scores}}$ values of hummingbirds in the interaction networks (Table 2).

Table 2 – Models predicting the relation between the z-scores values of betweenness (BC) and closeness centrality (CC) and the morphological traits of hummingbird species in plant-hummingbird interaction networks across the Americas. The z-score values were obtained through randomizations of adjacency matrices described in the Material and Methods section. A dash indicates that the variable was absent in the minimum adequate model (MAM).

	$BC_{z\text{-scores}}$			$CC_{z\text{-scores}}$		
	$\Sigma\omega_i$	AVM	MAM	$\Sigma\omega_i$	AVM	MAM
Bill length	0.59	-0.91	-0.92	0.21	0.08	–
Bill curvature	0.46	-0.58	–	0.09	0.02	–
Wing chord	0.35	0.60	–	0.26	0.11	–

AVM – conditional averaged coefficients; BC – betweenness centrality; CC – closeness centrality; $\Sigma\omega_i$ – predictor variable importance described by the sum of Akaike weights (ω) of all models that a given variable was present; MAM – standardized coefficients of the minimum adequate model, which was the model with the lowest AIC_c. AVM and $\Sigma\omega_i$ were calculated with a subset of all models that represents a cumulative sum of Akaike weights (ω) $\leq$ 0.95.

Topological positions occupied by hummingbirds in the interaction networks were also predicted by their evolutionary history, with the occurrence of a low phylogenetic signal in DC (λ_μ = 0.19, p < 0.05) and a moderate phylogenetic signal in CC (λ_μ = 0.51, p < 0.05). Among the evolutionary clades, Bees, Emeralds and Mangoes showed high centrality values (Fig. 2). The relation between the topological positions and the evolutionary history of hummingbirds were detected in all the 1,000 phylogenetic hypotheses analysed, demonstrating that our results were not affected by the phylogenetic uncertainty created by the inclusion of some missing species in the backbone phylogeny (Table 3).

Table 3 – Phylogenetic signal in degree (DC), betweenness (BC) and closeness (CC) centrality of 158 hummingbird species in plant-hummingbird interaction networks across the Americas. The phylogenetic signal was estimated by Pagel's λ across 1,000 phylogenetical hypotheses using McGuire et al. (2014) as a backbone tree. Details about the phylogenies building can be found in the Material and Methods section.

	λ_{μ}	λ_{σ}	λ_{min}	λ_{max}
DC	0.19*	0.01	0.18	0.21
BC	0.00	0.00	0.00	0.00
CC	0.51*	0.03	0.45	0.60

BC – betweenness centrality; CC – closeness centrality; DC – degree centrality; max – maximum; min – minimum; λ – Pagel's λ; μ – mean; σ – standard deviation; * – $p < 0.05$ in the 1,000 phylogenetical hypotheses.

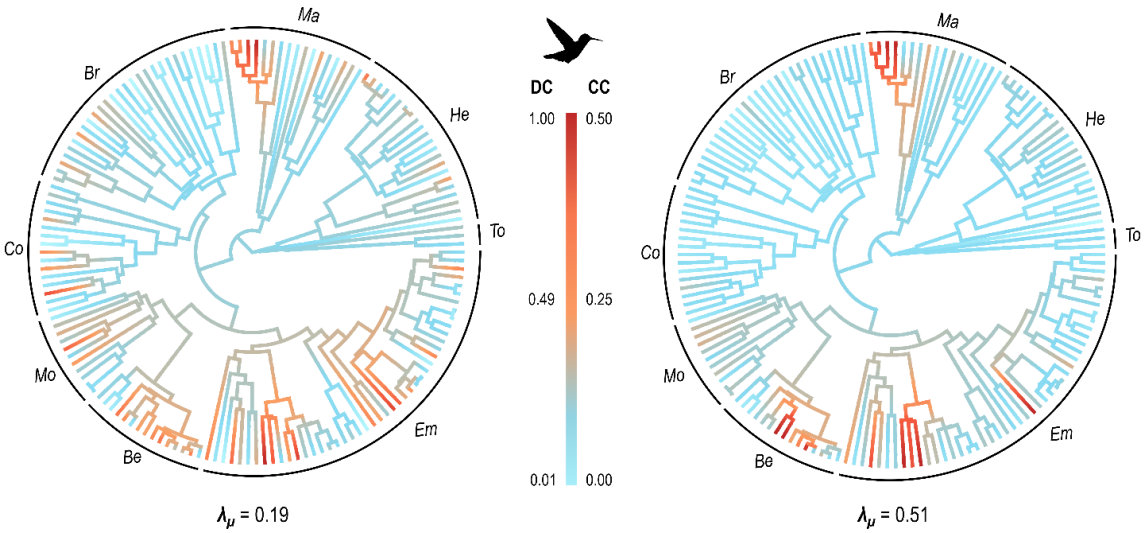

Fig. 2 – Phylogenetic signal (λ_{μ}) of the topological positions occupied by 158 hummingbird species in 74 plant-hummingbird interaction networks distributed across the Americas. Bees, Emeralds and Mangoes are keystone species in plant-hummingbird interaction networks. Keystone species are described by centrality level, which is represented by the colour scale. Phylogenetic hypothesis and clades following McGuire et al. (2014). **Be** – Bees, **Br** – Brilliants, **CC** – closeness centrality, **Co** – Coquettes, **DC –** degree centrality, **Em** – Emeralds**, He** – Hermits, **Ma** – Mangoes, **Mo** – Mountain gems, **To** – Topazes.

4. DISCUSSION

We found that both niche and neutral drivers affected the topological positions occupied by hummingbird species in plant-hummingbird interaction networks across the Americas. This result reinforces the importance of niche and neutral drivers in producing keystone

species in mutualistic networks (Stang et al. 2006, Krishna et al. 2008, Sazima et al. 2010, Schleuning et al. 2014).

Keystone hummingbirds tend to have straight bills, large wing chords and higher interaction frequencies, as expected (Snow and Snow 1972, Temeles et al. 2002b). However, differently from expected, we detected that keystone positions identified by CC and $BC_{z\text{-}score}$ values tended also to be related with short bills. These results highlight that different keystone roles were performed by hummingbirds that combine different traits and higher interaction frequencies. Specifically, the keystone role of maintaining the ecosystem functioning by pollinating a higher proportion of plant species in the community were performed by hummingbirds with larger wing chords and higher interaction frequencies. On the other hand, the maintenance of ecosystem structure and stability by pollinating plant species from different guilds was maintained by hummingbirds with straight bills and higher interaction frequencies. Finally, the keystone role of summarizing different functions by pollinating plant species that are visited by different hummingbirds in the community were maintained by hummingbirds with short bill and higher interaction frequencies.

We also detected that the performance of this last keystone role was phylogenetically conserved across the evolutionary history of hummingbirds, with the evolutionary clades of Bees, Emeralds and Mangoes showing higher centrality values. This pattern highlights the relevance of evolutionary history in shaping species functions in ecological communities, as detected in other mutualistic networks (Rezende et al. 2007, Mello et al. 2013, Schleuning et al. 2014). The divergence among the predictor variables that best explained the variation in centrality metrics, as well as the low correlation found among these metrics indicate that different species and ecological traits are important to

maintain community structure and stability. Therefore, contrarily to the high correlation of centrality metrics found in other mutualistic networks (Martín González et al. 2010, Sazima et al. 2010), our results stress the higher complexity in the organization of plant-hummingbird interaction networks. Then, the importance in maintaining community integrity and dynamics is distributed across different hummingbird species, which may ensure a higher robustness to the system.

The relations found between species morphological traits and their topological positions were lost when we analysed the expected patterns of interactions according to species interaction frequencies. However, hummingbird species with short bills tend to occupy more central positions than expected by their interaction frequencies, showing that a pure niche-related driver determines the topological position occupied by these species in the interaction networks. The loss of relation between species morphological traits and their topological positions could indicate that although keystone species can be predicted by their morphological traits, their occurrence may be regulated by a neutral-related driver, with morphological traits related to keystone roles being the most abundant trait in the community. However, curiously, we detected a low correlation between species morphological traits and interaction frequencies ($\rho_{IF\text{-}BL} = 0.06$, $\rho_{IF\text{-}BCu} = 0.07$, $\rho_{IF\text{-}WC} = 0.04$, $p > 0.05$). Actually, species interaction frequencies predicted the topological position of hummingbirds in all centrality metrics. Additionally, central positions identified by DC were mainly described by species interaction frequencies, as detected by the few observations of DC values higher than expected by their interaction frequencies. Thus, all of these patterns combined stress the high importance of neutral-related drivers in producing keystone species in plant-hummingbird interaction networks, as well as in other mutualistic networks (Stang et al. 2006, Vázquez et al. 2007, Krishna et al. 2008, Sazima

et al. 2010, Schleuning et al. 2014). However, this high importance of neutral-related drivers for plant-hummingbird networks is surprising, since species morphological constrains were already detected as a major factor in predicting plant-hummingbird interactions (Maruyama et al. 2014, Vizentin-Bugoni et al. 2014a).

Our findings besides contributing to understand the patterns of interactions within the communities, also have conservation implications (Caro 2010). Although conservation efforts tend to be focused in rarity (Rabinowitz 1981, IUCN 2017), our results highlight the importance of species that interact more in maintaining keystone roles in the ecosystem. This importance of species with higher interaction frequencies for ecosystem functioning ensure a higher robustness to the system, since abundant interactions are less prone to extinction than rare interactions (Pimm et al. 1988). However, although there is a convergence between morphological traits of keystone species and morphological extinction selectivity, where hummingbirds with short and straight bills are more prone to extinction than hummingbirds with long and curved bills (Zanata et al. *in prep*., Chapter 3 of this thesis), keystone species may be at higher chances of extinction vulnerability.

Another vulnerability that we found in the system is the pattern of distribution of keystone species across the evolutionary history of hummingbirds, with a keystone role being concentrated in a few evolutionary clades. This evolutionary clumping makes the system more vulnerable than when it is dispersed across the evolutionary history (Rezende et al. 2007). However, the extinction selectivity detected across the evolutionary history of hummingbirds did not encompasses the clades associated with keystone roles in plant-hummingbird networks, with Mangoes having no species vulnerable to extinction and Bees and Emeralds having a low proportion of vulnerable species (IUCN 2017, Zanata

et al., *in prep.*, Chapter 3 of this thesis). Therefore, these keystone roles may be protected against extirpation due to hummingbird extinction vulnerability.

In conclusion, our findings reinforce the complex interplay of niche and neutral drivers in producing keystone species in mutualistic networks. Specifically, we identified that hummingbird species with short and straight bills, large wing chords, higher interaction frequencies and belonging to the evolutionary clades of Bees, Emeralds and Mangoes are the most important species to maintain ecosystem functioning and stability of plant-hummingbird networks. Also, our results stress the importance in developing a conservation policy based on important species, rather than only on rare species, when the goal is maintaining the community structure and its associated ecosystem functions and services.

ACKNOWLEDGMENTS

We thank André C. Guaraldo and Tiago S. Malucelli for their help with the analyses and Tiago M. Sousa for his help with the figures.

FUNDING

This study was funded by CAPES Foundation (PDSE scholarship proc. 8105/2014-6 to TBZ), CNPq (PQ scholarship 309453/2013-5 to IGV), MCTI/CNPQ/UNIVERSAL (proc. 445405/2014-7), Center for Macroecology, Evolution and Climate (CMEC) and Danish Council for Independent Research Natural Sciences.

AUTHORS CONTRIBUTION

TBZ, IGV and BD conceived the ideas, TBZ performed the analyses, TBZ, IGV and BD wrote the first draft of the manuscript, and all authors contributed with revisions.

SUPPLEMENTARY MATERIAL

APPENDIX S1 – Plant-hummingbird interaction networks descriptions (available at the "Material Suplementar" section, p. 162).

APPENDIX S2 – Morphological traits measurements (available at the "Material Suplementar" section, p. 171).

APPENDIX S3 – Inclusion methods of the species missing in the phylogeny of McGuire et al. (2014) (available at the "Material Suplementar" section, p. 173).

APPENDIX S4 – Centrality metrics values of hummingbird species in each interaction network

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6. SUPPLEMENTARY MATERIAL

APPENDIX S4 – CENTRALITY METRICS VALUES OF HUMMINGBIRD SPECIES IN EACH INTERACTION NETWORK.

Table S2 – Centrality metrics values of 158 hummingbird species in 74 plant-hummingbird interaction networks distributed across the Americas

Network ID	Hummingbird species	Degree centrality	Betweenness centrality	Closeness centrality
1	*Amazilia fimbriata*	0.642857	0.000000	0.129921
1	*Amazilia lactea*	0.285714	0.000000	0.098425
1	*Calliphlox amethystina*	0.142857	0.000000	0.102362
1	*Chlorostilbon lucidus*	0.714286	0.000000	0.102362
1	*Phaethornis pretrei*	0.214286	0.000000	0.129921
1	*Phaethornis ruber*	0.071429	0.166667	0.141732
1	*Phaethornis squalidus*	0.071429	0.666667	0.153543
1	*Thalurania glaucopis*	0.142857	0.166667	0.141732
2	*Selasphorus calliope*	0.500000	0.000000	0.500000
2	*Selasphorus rufus*	1.000000	0.000000	0.500000
3	*Selasphorus platycercus*	1.000000	0.000000	0.500000
3	*Selasphorus rufus*	1.000000	0.000000	0.500000
4	*Amazilia brevirostris*	0.071429	0.017391	0.082569
4	*Amazilia fimbriata*	0.071429	0.310870	0.100917
4	*Anthracothorax nigricollis*	0.142857	0.032609	0.082569
4	*Eupetomena macroura*	0.166667	0.000000	0.064220
4	*Florisuga fusca*	0.452381	0.089855	0.087156
4	*Glaucis hirsutus*	0.309524	0.000000	0.073394
4	*Hylocharis cyanus*	0.428571	0.173188	0.096330
4	*Leucochloris albicollis*	0.047619	0.000000	0.077982
4	*Lophornis chalybeus*	0.214286	0.021739	0.077982
4	*Phaethornis ruber*	0.190476	0.021739	0.077982
4	*Ramphodon naevius*	0.214286	0.021739	0.077982
4	*Thalurania glaucopis*	0.023810	0.310870	0.100917
5	*Eupetomena macroura*	0.076923	0.000000	0.222222
5	*Hylocharis chrysura*	0.923077	1.000000	0.333333
5	*Phaethornis eurynome*	0.153846	0.000000	0.222222
5	*Polytmus guainumbi*	0.153846	0.000000	0.222222
6	*Amazilia rutila*	0.066667	0.333333	0.210526
6	*Archilochus colubris*	0.466667	0.000000	0.184211
6	*Chlorostilbon canivetii*	0.866667	0.000000	0.184211
6	*Cynanthus latirostris*	0.533333	0.333333	0.210526
6	*Heliomaster constantii*	0.333333	0.333333	0.210526
7	*Amazilia fimbriata*	0.066667	0.000000	0.135135
7	*Anthracothorax nigricollis*	0.733333	0.050000	0.148649

7	*Chlorostilbon lucidus*	0.066667	0.450000	0.162162
7	*Eupetomena macroura*	0.333333	0.450000	0.162162
7	*Heliomaster squamosus*	0.066667	0.000000	0.108108
7	*Hylocharis chrysura*	0.733333	0.050000	0.148649
7	*Thalurania furcata*	0.133333	0.000000	0.135135
8	*Aglaeactis cupripennis*	0.052632	0.194444	0.125000
8	*Coeligena iris*	0.947368	0.083333	0.116667
8	*Colibri coruscans*	0.578947	0.000000	0.091667
8	*Eriocnemis luciani*	0.421053	0.361111	0.133333
8	*Heliangelus viola*	0.052632	0.000000	0.091667
8	*Lafresnaya lafresnayi*	0.052632	0.000000	0.091667
8	*Lesbia nuna*	0.052632	0.000000	0.108333
8	*Metallura tyrianthina*	0.052632	0.361111	0.133333
8	*Pterophanes cyanopterus*	0.526316	0.000000	0.108333
9	*Coeligena iris*	0.050000	0.000000	0.142857
9	*Colibri coruscans*	0.850000	0.000000	0.142857
9	*Ensifera ensifera*	0.400000	0.000000	0.000000
9	*Eriocnemis luciani*	0.250000	0.000000	0.142857
9	*Heliangelus viola*	0.500000	0.000000	0.142857
9	*Lafresnaya lafresnayi*	0.150000	0.000000	0.142857
9	*Metallura tyrianthina*	0.300000	0.000000	0.142857
9	*Pterophanes cyanopterus*	0.100000	0.000000	0.142857
10	*Chaetocercus mulsant*	0.052632	0.000000	0.066129
10	*Coeligena iris*	0.421053	0.351111	0.096774
10	*Colibri coruscans*	0.263158	0.005556	0.087097
10	*Ensifera ensifera*	0.105263	0.000000	0.054839
10	*Eriocnemis luciani*	0.105263	0.095556	0.096774
10	*Heliangelus viola*	0.052632	0.000000	0.082258
10	*Lafresnaya lafresnayi*	0.210526	0.017778	0.091935
10	*Lesbia victoriae*	0.578947	0.000000	0.082258
10	*Metallura baroni*	0.105263	0.095556	0.096774
10	*Metallura tyrianthina*	0.210526	0.428889	0.101613
10	*Pterophanes cyanopterus*	0.157895	0.005556	0.087097
10	*Ramphomicron microrhynchum*	0.526316	0.000000	0.056452
11	*Anthracothorax nigricollis*	1.000000	0.000000	0.108108
11	*Chlorostilbon lucidus*	0.187500	0.000000	0.135135
11	*Florisuga fusca*	0.187500	0.300000	0.148649
11	*Hylocharis chrysura*	0.250000	0.550000	0.162162
11	*Leucochloris albicollis*	0.187500	0.050000	0.148649
11	*Stephanoxis lalandi*	0.187500	0.050000	0.148649
11	*Thalurania glaucopis*	0.125000	0.050000	0.148649
12	*Amazilia fimbriata*	0.045455	0.051111	0.083333
12	*Amazilia versicolor*	0.045455	0.517778	0.095238
12	*Calliphlox amethystina*	0.272727	0.000000	0.059524
12	*Clytolaema rubricauda*	0.409091	0.000000	0.071429
12	*Florisuga fusca*	0.045455	0.051111	0.083333

12	*Glaucis hirsutus*	0.181818	0.011111	0.075397
12	*Heliomaster squamosus*	0.090909	0.000000	0.059524
12	*Hylocharis cyanus*	0.090909	0.011111	0.071429
12	*Leucochloris albicollis*	0.318182	0.000000	0.071429
12	*Phaethornis ruber*	0.181818	0.177778	0.079365
12	*Phaethornis squalidus*	0.363636	0.011111	0.075397
12	*Ramphodon naevius*	0.500000	0.084444	0.087302
12	*Thalurania glaucopis*	0.272727	0.084444	0.087302
13	*Clytolaema rubricauda*	0.906250	0.000000	0.184211
13	*Leucochloris albicollis*	0.593750	0.000000	0.184211
13	*Phaethornis eurynome*	0.218750	0.333333	0.210526
13	*Phaethornis squalidus*	0.062500	0.333333	0.210526
13	*Thalurania glaucopis*	0.562500	0.333333	0.210526
14	*Calliphlox amethystina*	0.064516	0.000000	0.200000
14	*Chlorostilbon lucidus*	0.935484	0.000000	0.200000
14	*Chrysolampis mosquitus*	0.354839	0.000000	0.200000
14	*Eupetomena macroura*	0.193548	0.000000	0.200000
14	*Heliomaster squamosus*	0.354839	0.000000	0.200000
15	*Amazilia fimbriata*	0.925926	0.000000	0.088235
15	*Amazilia lactea*	0.185185	0.000000	0.127451
15	*Anopetia gounellei*	0.259259	0.000000	0.127451
15	*Chlorostilbon lucidus*	0.111111	0.500000	0.137255
15	*Chrysolampis mosquitus*	0.074074	0.000000	0.127451
15	*Eupetomena macroura*	0.185185	0.500000	0.137255
15	*Heliomaster squamosus*	0.222222	0.000000	0.127451
15	*Phaethornis pretrei*	0.037037	0.000000	0.127451
16	*Adelomyia melanogenys*	0.444444	0.000000	0.108696
16	*Boissonneaua flavescens*	0.296296	0.000000	0.119565
16	*Coeligena torquata*	0.074074	0.433333	0.152174
16	*Eriocnemis mirabilis*	0.037037	0.433333	0.152174
16	*Haplophaedia aureliae*	0.481481	0.066667	0.130435
16	*Heliangelus exortis*	0.555556	0.000000	0.108696
16	*Metallura tyrianthina*	0.037037	0.066667	0.130435
16	*Phaethornis syrmatophorus*	0.111111	0.000000	0.097826
17	*Amazilia leucogaster*	0.062500	0.000000	0.080863
17	*Aphantochroa cirrochloris*	0.812500	0.070707	0.084906
17	*Chlorestes notata*	0.312500	0.000000	0.055256
17	*Chrysolampis mosquitus*	0.125000	0.000000	0.080863
17	*Eupetomena macroura*	0.062500	0.000000	0.080863
17	*Glaucis dohrnii*	0.500000	0.000000	0.059299
17	*Glaucis hirsutus*	0.062500	0.070707	0.084906
17	*Heliothryx auritus*	0.125000	0.000000	0.080863
17	*Hylocharis cyanus*	0.187500	0.000000	0.060647
17	*Phaethornis malaris*	0.125000	0.000000	0.056604
17	*Phaethornis pretrei*	0.062500	0.313131	0.092992
17	*Phaethornis ruber*	0.125000	0.348485	0.092992

17	*Thalurania glaucopis*	0.250000	0.196970	0.088949
18	*Amazilia fimbriata*	0.137931	0.129433	0.079108
18	*Anthracothorax nigricollis*	0.241379	0.063475	0.069980
18	*Campylopterus largipennis*	0.068966	0.005319	0.066937
18	*Chlorestes notata*	0.172414	0.000000	0.057809
18	*Chlorostilbon mellisugus*	0.068966	0.005319	0.066937
18	*Chrysuronia oenone*	0.241379	0.129433	0.079108
18	*Florisuga mellivora*	0.068966	0.000000	0.057809
18	*Glaucis hirsutus*	0.103448	0.101064	0.076065
18	*Heliodoxa aurescens*	0.379310	0.000000	0.043611
18	*Phaethornis bourcieri*	0.448276	0.000000	0.051724
18	*Phaethornis hispidus*	0.482759	0.023404	0.068966
18	*Phaethornis ruber*	0.034483	0.005319	0.066937
18	*Phaethornis superciliosus*	0.172414	0.101064	0.076065
18	*Thalurania furcata*	0.137931	0.436170	0.079108
18	*Threnetes leucurus*	0.310345	0.000000	0.059838
19	*Chlorostilbon ricordii*	1.000000	0.000000	0.500000
19	*Mellisuga helenae*	0.500000	0.000000	0.500000
20	*Cyanophaia bicolor*	0.750000	1.000000	0.400000
20	*Eulampis jugularis*	0.583333	0.000000	0.300000
20	*Orthorhyncus cristatus*	0.250000	0.000000	0.300000
21	*Eulampis holosericeus*	0.454545	0.000000	0.500000
21	*Orthorhyncus cristatus*	0.818182	0.000000	0.500000
22	*Amazilia fimbriata*	0.062500	0.000000	0.250000
22	*Amazilia versicolor*	0.062500	0.000000	0.000000
22	*Phaethornis squalidus*	0.062500	0.000000	0.250000
22	*Ramphodon naevius*	0.187500	0.000000	0.250000
22	*Thalurania glaucopis*	0.937500	0.000000	0.250000
23	*Amazilia fimbriata*	0.071429	0.297778	0.105263
23	*Amazilia versicolor*	0.107143	0.120000	0.100000
23	*Eupetomena macroura*	0.107143	0.054444	0.094737
23	*Florisuga fusca*	0.035714	0.026667	0.089474
23	*Glaucis hirsutus*	0.571429	0.000000	0.068421
23	*Hylocharis cyanus*	0.035714	0.000000	0.078947
23	*Lophornis chalybeus*	0.535714	0.011111	0.089474
23	*Phaethornis ruber*	0.500000	0.000000	0.078947
23	*Phaethornis squalidus*	0.392857	0.137778	0.094737
23	*Ramphodon naevius*	0.285714	0.054444	0.094737
23	*Thalurania glaucopis*	0.214286	0.297778	0.105263
24	*Florisuga fusca*	0.750000	0.000000	0.194444
24	*Hylocharis cyanus*	0.166667	0.000000	0.194444
24	*Phaethornis eurynome*	0.208333	0.000000	0.166667
24	*Ramphodon naevius*	0.583333	0.500000	0.222222
24	*Thalurania glaucopis*	0.041667	0.500000	0.222222
25	*Eulampis holosericeus*	0.428571	0.000000	0.500000
25	*Orthorhyncus cristatus*	1.000000	0.000000	0.500000

26	*Eulampis holosericeus*	0.857143	0.000000	0.333333
26	*Glaucis hirsutus*	0.428571	0.000000	0.333333
26	*Orthorhyncus cristatus*	0.714286	0.000000	0.333333
27	*Aglaeactis cupripennis*	0.096774	0.086364	0.122951
27	*Chalcostigma herrani*	0.806452	0.000000	0.106557
27	*Coeligena lutetiae*	0.354839	0.000000	0.098361
27	*Ensifera ensifera*	0.387097	0.000000	0.073770
27	*Eriocnemis derbyi*	0.032258	0.086364	0.122951
27	*Eriocnemis mosquera*	0.322581	0.722727	0.131148
27	*Lafresnaya lafresnayi*	0.096774	0.000000	0.106557
27	*Metallura tyrianthina*	0.193548	0.018182	0.114754
27	*Pterophanes cyanopterus*	0.258065	0.086364	0.122951
28	*Mellisuga minima*	0.500000	0.000000	0.500000
28	*Trochilus polytmus*	0.833333	0.000000	0.500000
29	*Amazilia fimbriata*	0.125000	0.000000	0.500000
29	*Eupetomena macroura*	1.000000	0.000000	0.500000
30	*Amazilia fimbriata*	0.111111	0.071429	0.173913
30	*Amazilia versicolor*	0.111111	0.000000	0.152174
30	*Clytolaema rubricauda*	0.111111	0.000000	0.152174
30	*Phaethornis eurynome*	0.500000	0.000000	0.152174
30	*Ramphodon naevius*	0.555556	0.000000	0.152174
30	*Thalurania glaucopis*	0.222222	0.928571	0.217391
31	*Amazilia versicolor*	0.400000	0.000000	0.211538
31	*Clytolaema rubricauda*	0.100000	0.500000	0.288462
31	*Phaethornis eurynome*	0.600000	0.000000	0.211538
31	*Thalurania glaucopis*	0.500000	0.500000	0.288462
32	*Amazilia versicolor*	0.714286	0.000000	0.250000
32	*Clytolaema rubricauda*	0.714286	0.000000	0.250000
32	*Stephanoxis lalandi*	0.571429	0.000000	0.250000
32	*Thalurania glaucopis*	0.142857	0.000000	0.250000
33	*Archilochus colubris*	0.090909	0.000000	0.096591
33	*Basilinna leucotis*	0.545455	0.142857	0.102273
33	*Calothorax lucifer*	1.000000	0.000000	0.096591
33	*Colibri thalassinus*	0.181818	0.142857	0.102273
33	*Eugenes fulgens*	0.818182	0.142857	0.102273
33	*Lampornis amethystinus*	0.545455	0.000000	0.090909
33	*Lampornis clemenciae*	0.454545	0.142857	0.102273
33	*Selasphorus platycercus*	0.454545	0.142857	0.102273
33	*Selasphorus rufus*	0.454545	0.142857	0.102273
33	*Selasphorus sasin*	0.363636	0.142857	0.102273
34	*Amazilia beryllina*	0.750000	0.000000	0.160714
34	*Archilochus colubris*	1.000000	0.000000	0.160714
34	*Basilinna leucotis*	0.500000	0.333333	0.178571
34	*Calothorax lucifer*	1.000000	0.000000	0.142857
34	*Cynanthus latirostris*	1.000000	0.333333	0.178571
34	*Eugenes fulgens*	0.250000	0.333333	0.178571

35	*Amazilia beryllina*	0.750000	0.000000	0.090909
35	*Amazilia candida*	0.750000	0.000000	0.090909
35	*Amazilia cyanocephala*	0.500000	0.000000	0.090909
35	*Amazilia yucatanensis*	0.500000	0.000000	0.090909
35	*Anthracothorax prevostii*	0.250000	0.000000	0.090909
35	*Atthis heloisa*	0.250000	0.000000	0.090909
35	*Campylopterus curvipennis*	0.250000	0.000000	0.090909
35	*Campylopterus hemileucurus*	0.250000	0.000000	0.090909
35	*Colibri thalassinus*	0.250000	0.000000	0.090909
35	*Eugenes fulgens*	0.250000	0.000000	0.090909
35	*Lampornis amethystinus*	0.250000	0.000000	0.090909
36	*Amazilia versicolor*	0.909091	0.000000	0.088889
36	*Chlorostilbon olivaresi*	0.340909	0.000000	0.111111
36	*Florisuga mellivora*	0.159091	0.000000	0.122222
36	*Phaethornis bourcieri*	0.022727	0.727273	0.155556
36	*Phaethornis malaris*	0.022727	0.060606	0.133333
36	*Phaethornis ruber*	0.022727	0.030303	0.122222
36	*Thalurania furcata*	0.181818	0.181818	0.144444
36	*Topaza pyra*	0.340909	0.000000	0.122222
37	*Amazilia lactea*	0.085714	0.200000	0.146341
37	*Augastes lumachella*	0.485714	0.000000	0.134146
37	*Calliphlox amethystina*	0.142857	0.000000	0.134146
37	*Chlorostilbon lucidus*	0.142857	0.200000	0.146341
37	*Chrysolampis mosquitus*	0.257143	0.200000	0.146341
37	*Colibri serrirostris*	0.828571	0.200000	0.146341
37	*Phaethornis pretrei*	0.228571	0.200000	0.146341
38	*Amazilia lactea*	0.071429	0.000000	0.142857
38	*Anopetia gounellei*	0.321429	0.000000	0.142857
38	*Chlorostilbon lucidus*	0.071429	0.000000	0.142857
38	*Chrysolampis mosquitus*	0.321429	0.000000	0.142857
38	*Colibri serrirostris*	0.714286	0.000000	0.142857
38	*Eupetomena macroura*	0.642857	0.000000	0.142857
38	*Phaethornis pretrei*	0.464286	0.000000	0.142857
39	*Anopetia gounellei*	0.272727	0.071429	0.132653
39	*Calliphlox amethystina*	0.181818	0.000000	0.122449
39	*Chlorostilbon lucidus*	0.818182	0.071429	0.132653
39	*Chrysolampis mosquitus*	0.090909	0.000000	0.122449
39	*Colibri serrirostris*	0.090909	0.428571	0.142857
39	*Eupetomena macroura*	0.090909	0.000000	0.091837
39	*Heliactin bilophus*	0.363636	0.428571	0.142857
39	*Phaethornis pretrei*	0.454545	0.000000	0.112245
40	*Doryfera ludovicae*	0.040000	0.000000	0.138889
40	*Eupherusa nigriventris*	0.040000	0.041667	0.152778
40	*Eutoxeres aquila*	0.080000	0.000000	0.000000
40	*Heliodoxa jacula*	0.120000	0.000000	0.097222
40	*Lampornis calolaemus*	0.480000	0.041667	0.152778

40	*Lampornis hemileucus*	0.520000	0.041667	0.152778
40	*Phaethornis guy*	0.120000	0.875000	0.166667
40	*Phaethornis striigularis*	0.520000	0.000000	0.138889
41	*Campylopterus hemileucurus*	0.100000	0.000000	0.098160
41	*Doryfera ludovicae*	0.250000	0.000000	0.110429
41	*Eugenes fulgens*	0.100000	0.000000	0.092025
41	*Heliodoxa jacula*	0.300000	0.000000	0.098160
41	*Lampornis calolaemus*	0.050000	0.394737	0.138037
41	*Panterpe insignis*	0.100000	0.131579	0.119632
41	*Phaethornis guy*	0.050000	0.210526	0.128834
41	*Selasphorus flammula*	0.250000	0.263158	0.128834
41	*Selasphorus scintilla*	0.650000	0.000000	0.085890
42	*Amazilia tzacatl*	0.045455	0.125000	0.158654
42	*Florisuga mellivora*	0.045455	0.000000	0.000000
42	*Klais guimeti*	0.045455	0.000000	0.144231
42	*Phaeochroa cuvierii*	0.590909	0.000000	0.125000
42	*Phaethornis longirostris*	0.454545	0.125000	0.158654
42	*Phaethornis striigularis*	0.363636	0.625000	0.158654
42	*Thalurania colombica*	0.045455	0.125000	0.158654
42	*Threnetes ruckeri*	0.272727	0.000000	0.096154
43	*Amazilia fimbriata*	0.125000	0.175000	0.121875
43	*Amazilia versicolor*	0.166667	0.066667	0.112500
43	*Aphantochroa cirrochloris*	0.666667	0.000000	0.090625
43	*Chlorostilbon lucidus*	0.041667	0.000000	0.087500
43	*Florisuga fusca*	0.083333	0.158333	0.121875
43	*Lophornis chalybeus*	0.166667	0.000000	0.090625
43	*Phaethornis eurynome*	0.041667	0.000000	0.103125
43	*Phaethornis squalidus*	0.500000	0.000000	0.000000
43	*Ramphodon naevius*	0.041667	0.183333	0.131250
43	*Thalurania glaucopis*	0.083333	0.416667	0.140625
44	*Amazilia fimbriata*	0.823529	0.216667	0.132075
44	*Calliphlox amethystina*	0.705882	0.000000	0.113208
44	*Chlorostilbon lucidus*	0.117647	0.216667	0.132075
44	*Colibri serrirostris*	0.117647	0.216667	0.132075
44	*Eupetomena macroura*	0.588235	0.216667	0.132075
44	*Heliomaster squamosus*	0.470588	0.066667	0.122642
44	*Hylocharis chrysura*	0.294118	0.000000	0.113208
44	*Phaethornis pretrei*	0.411765	0.066667	0.122642
45	*Amazilia fimbriata*	0.142857	0.000000	0.125000
45	*Chlorostilbon lucidus*	0.085714	0.000000	0.125000
45	*Colibri serrirostris*	0.542857	0.000000	0.125000
45	*Eupetomena macroura*	0.571429	0.000000	0.125000
45	*Heliomaster squamosus*	0.371429	0.000000	0.125000
45	*Lophornis magnificus*	0.400000	0.000000	0.125000
45	*Phaethornis pretrei*	0.400000	0.000000	0.125000
45	*Thalurania furcata*	0.428571	0.000000	0.125000

46	*Amazilia fimbriata*	0.416667	0.000000	0.111111
46	*Calliphlox amethystina*	0.500000	0.000000	0.111111
46	*Chlorostilbon lucidus*	0.500000	0.000000	0.111111
46	*Chrysolampis mosquitus*	0.416667	0.000000	0.111111
46	*Colibri serrirostris*	0.166667	0.000000	0.111111
46	*Eupetomena macroura*	0.166667	0.000000	0.111111
46	*Heliactin bilophus*	0.416667	0.000000	0.111111
46	*Lophornis magnificus*	0.083333	0.000000	0.111111
46	*Thalurania furcata*	0.083333	0.000000	0.111111
47	*Amazilia beryllina*	0.222222	0.200000	0.087302
47	*Amazilia candida*	0.444444	0.000000	0.083333
47	*Amazilia cyanocephala*	0.444444	0.200000	0.087302
47	*Amazilia yucatanensis*	0.666667	0.000000	0.083333
47	*Anthracothorax prevostii*	0.333333	0.000000	0.083333
47	*Atthis heloisa*	0.111111	0.200000	0.087302
47	*Campylopterus curvipennis*	0.111111	0.200000	0.087302
47	*Campylopterus hemileucurus*	0.222222	0.000000	0.083333
47	*Colibri thalassinus*	0.111111	0.000000	0.083333
47	*Eugenes fulgens*	0.444444	0.000000	0.083333
47	*Lampornis amethystinus*	0.111111	0.200000	0.087302
47	*Lamprolaima rhami*	0.111111	0.000000	0.063492
48	*Basilinna leucotis*	0.857143	0.000000	0.333333
48	*Eugenes fulgens*	0.285714	0.000000	0.333333
48	*Lampornis clemenciae*	0.285714	0.000000	0.333333
49	*Amazilia violiceps*	0.727273	0.000000	0.159091
49	*Archilochus alexandri*	0.181818	0.000000	0.159091
49	*Archilochus colubris*	0.545455	0.500000	0.238636
49	*Calothorax lucifer*	0.090909	0.000000	0.204545
49	*Cynanthus latirostris*	0.090909	0.500000	0.238636
50	*Archilochus colubris*	0.826087	0.000000	0.105634
50	*Basilinna leucotis*	0.304348	0.142857	0.112676
50	*Calothorax lucifer*	0.521739	0.142857	0.112676
50	*Colibri thalassinus*	0.826087	0.000000	0.105634
50	*Cynanthus latirostris*	0.347826	0.142857	0.112676
50	*Eugenes fulgens*	0.347826	0.142857	0.112676
50	*Lampornis clemenciae*	0.217391	0.142857	0.112676
50	*Selasphorus platycercus*	0.304348	0.142857	0.112676
50	*Selasphorus rufus*	0.173913	0.142857	0.112676
51	*Basilinna leucotis*	0.777778	0.000000	0.500000
51	*Eugenes fulgens*	0.333333	0.000000	0.500000
52	*Anthracothorax viridis*	0.909091	0.000000	0.500000
52	*Chlorostilbon maugaeus*	0.272727	0.000000	0.500000
53	*Anthracothorax dominicus*	1.000000	0.000000	0.500000
53	*Chlorostilbon maugaeus*	0.200000	0.000000	0.500000
54	*Adelomyia melanogenys*	0.347826	0.000000	0.076923
54	*Aglaiocercus kingii*	0.260870	0.000000	0.076923

54	*Amazilia franciae*	0.478261	0.000000	0.076923
54	*Amazilia saucerottei*	0.347826	0.000000	0.076923
54	*Amazilia tzacatl*	0.304348	0.000000	0.076923
54	*Anthracothorax nigricollis*	0.130435	0.000000	0.076923
54	*Boissonneaua flavescens*	0.173913	0.000000	0.076923
54	*Coeligena coeligena*	0.304348	0.000000	0.076923
54	*Colibri coruscans*	0.217391	0.000000	0.076923
54	*Doryfera ludovicae*	0.347826	0.000000	0.076923
54	*Florisuga mellivora*	0.434783	0.000000	0.076923
54	*Ocreatus underwoodii*	0.434783	0.000000	0.076923
54	*Phaethornis guy*	0.260870	0.000000	0.076923
55	*Amazilia saucerottei*	0.142857	0.000000	0.166667
55	*Amazilia tzacatl*	0.571429	0.000000	0.166667
55	*Anthracothorax nigricollis*	0.642857	0.000000	0.166667
55	*Chlorostilbon mellisugus*	0.357143	0.000000	0.166667
55	*Heliomaster longirostris*	0.714286	0.000000	0.166667
55	*Phaethornis guy*	0.857143	0.000000	0.166667
56	*Amazilia versicolor*	0.027778	0.000000	0.081911
56	*Anthracothorax nigricollis*	0.027778	0.114286	0.092150
56	*Aphantochroa cirrochloris*	0.027778	0.000000	0.076792
56	*Chlorostilbon lucidus*	0.138889	0.000000	0.064846
56	*Clytolaema rubricauda*	0.055556	0.000000	0.076792
56	*Florisuga fusca*	0.666667	0.014286	0.087031
56	*Leucochloris albicollis*	0.111111	0.000000	0.076792
56	*Lophornis chalybeus*	0.722222	0.000000	0.071672
56	*Phaethornis eurynome*	0.027778	0.000000	0.059727
56	*Phaethornis squalidus*	0.027778	0.090476	0.097270
56	*Ramphodon naevius*	0.361111	0.447619	0.107509
56	*Thalurania glaucopis*	0.111111	0.333333	0.107509
57	*Amazilia fimbriata*	0.615385	0.250000	0.150000
57	*Anthracothorax nigricollis*	0.615385	0.250000	0.150000
57	*Chlorostilbon lucidus*	0.230769	0.250000	0.150000
57	*Eupetomena macroura*	0.384615	0.000000	0.125000
57	*Florisuga fusca*	0.230769	0.000000	0.137500
57	*Hylocharis chrysura*	0.153846	0.250000	0.150000
57	*Thalurania furcata*	0.076923	0.000000	0.137500
58	*Augastes scutatus*	0.060000	0.500000	0.185185
58	*Campylopterus largipennis*	0.300000	0.500000	0.185185
58	*Chlorostilbon lucidus*	0.100000	0.000000	0.129630
58	*Colibri serrirostris*	0.140000	0.000000	0.166667
58	*Eupetomena macroura*	0.620000	0.000000	0.166667
58	*Phaethornis pretrei*	0.320000	0.000000	0.166667
59	*Chlorostilbon lucidus*	0.080000	0.000000	0.200000
59	*Clytolaema rubricauda*	0.040000	0.000000	0.200000
59	*Colibri serrirostris*	0.720000	0.000000	0.000000
59	*Leucochloris albicollis*	0.720000	0.000000	0.200000

59	*Phaethornis eurynome*	0.280000	0.000000	0.200000
59	*Stephanoxis lalandi*	0.520000	0.000000	0.200000
60	*Amazilia brevirostris*	0.614035	0.142857	0.112676
60	*Amazilia tobaci*	0.210526	0.142857	0.112676
60	*Anthracothorax nigricollis*	0.421053	0.142857	0.112676
60	*Chlorestes notata*	0.228070	0.142857	0.112676
60	*Chrysolampis mosquitus*	0.421053	0.000000	0.105634
60	*Florisuga mellivora*	0.578947	0.142857	0.112676
60	*Glaucis hirsutus*	0.122807	0.142857	0.112676
60	*Phaethornis guy*	0.368421	0.000000	0.105634
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61	*Ensifera ensifera*	0.384615	0.000000	0.000000
61	*Eriocnemis cupreoventris*	0.076923	0.000000	0.125000
61	*Eriocnemis vestita*	0.153846	0.000000	0.125000
61	*Heliangelus amethysticollis*	0.230769	0.000000	0.125000
61	*Lafresnaya lafresnayi*	0.538462	0.000000	0.125000
61	*Lesbia nuna*	0.153846	0.000000	0.125000
61	*Metallura tyrianthina*	0.615385	0.000000	0.125000
62	*Adelomyia melanogenys*	0.090909	0.234970	0.094828
62	*Aglaiocercus kingii*	0.090909	0.020833	0.077586
62	*Boissonneaua flavescens*	0.318182	0.121429	0.090517
62	*Chaetocercus mulsant*	0.181818	0.112500	0.086207
62	*Chlorostilbon poortmani*	0.409091	0.000000	0.068966
62	*Coeligena prunellei*	0.500000	0.044345	0.081897
62	*Coeligena torquata*	0.181818	0.010417	0.077586
62	*Colibri coruscans*	0.272727	0.049554	0.081897
62	*Colibri thalassinus*	0.136364	0.049554	0.081897
62	*Doryfera ludovicae*	0.090909	0.000000	0.073276
62	*Heliangelus amethysticollis*	0.272727	0.234970	0.094828
62	*Ocreatus underwoodii*	0.181818	0.121429	0.090517
63	*Amazilia cyanifrons*	0.230769	0.083333	0.173077
63	*Amazilia franciae*	0.384615	0.583333	0.192308
63	*Amazilia tzacatl*	0.461538	0.083333	0.173077
63	*Anthracothorax nigricollis*	0.153846	0.250000	0.173077
63	*Chlorostilbon gibsoni*	0.230769	0.000000	0.153846
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64	*Amazilia versicolor*	0.440000	0.000000	0.166667
64	*Clytolaema rubricauda*	0.200000	0.000000	0.166667
64	*Florisuga fusca*	0.480000	0.000000	0.166667
64	*Leucochloris albicollis*	0.440000	0.000000	0.166667
64	*Phaethornis eurynome*	0.200000	0.000000	0.166667
64	*Thalurania glaucopis*	0.440000	0.000000	0.166667
65	*Anthracothorax nigricollis*	0.333333	0.500000	0.171429
65	*Campylopterus largipennis*	0.666667	0.250000	0.192857

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67	*Florisuga fusca*	0.500000	0.000000	0.145833
67	*Phaethornis pretrei*	0.400000	0.000000	0.125000
68	*Adelomyia melanogenys*	0.052632	0.000000	0.066456
68	*Aglaiocercus coelestis*	0.052632	0.211210	0.082278
68	*Aglaiocercus kingii*	0.052632	0.000000	0.063291
68	*Boissonneaua flavescens*	0.052632	0.211210	0.082278
68	*Calliphlox mitchellii*	0.105263	0.000000	0.060127
68	*Coeligena torquata*	0.578947	0.120139	0.075949
68	*Coeligena wilsoni*	0.210526	0.149405	0.079114
68	*Doryfera ludovicae*	0.421053	0.000000	0.063291
68	*Ensifera ensifera*	0.368421	0.000000	0.063291
68	*Eriocnemis mirabilis*	0.157895	0.042460	0.072785
68	*Haplophaedia aureliae*	0.263158	0.211210	0.082278
68	*Heliangelus exortis*	0.368421	0.042460	0.072785
68	*Metallura tyrianthina*	0.157895	0.011905	0.069620
68	*Ocreatus underwoodii*	0.052632	0.000000	0.066456
69	*Amazilia versicolor*	0.017857	0.191667	0.117647
69	*Clytolaema rubricauda*	0.946429	0.191667	0.117647
69	*Eupetomena macroura*	0.071429	0.000000	0.095588
69	*Florisuga fusca*	0.142857	0.000000	0.102941
69	*Leucochloris albicollis*	0.125000	0.041667	0.110294
69	*Lophornis chalybeus*	0.107143	0.191667	0.117647
69	*Phaethornis eurynome*	0.071429	0.191667	0.117647
69	*Stephanoxis lalandi*	0.321429	0.000000	0.102941
69	*Thalurania glaucopis*	0.428571	0.191667	0.117647
70	*Adelomyia melanogenys*	0.015385	0.064957	0.053191
70	*Aglaiocercus coelestis*	0.030769	0.096515	0.054711
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70	*Amazilia tzacatl*	0.030769	0.096515	0.054711
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70	*Boissonneaua jardini*	0.015385	0.096515	0.054711
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70	*Coeligena wilsoni*	0.015385	0.096515	0.054711
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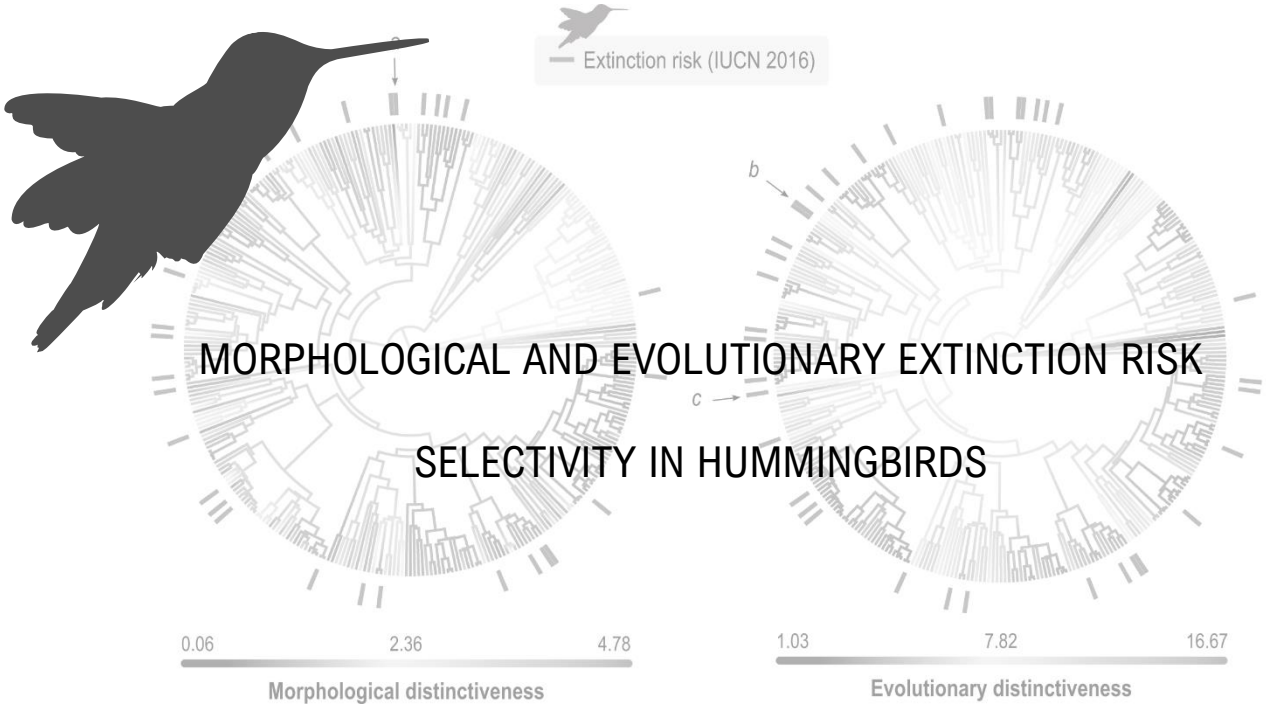
70	*Colibri delphinae*	0.076923	0.096515	0.054711

70	*Colibri thalassinus*	0.123077	0.000000	0.051672
70	*Doryfera ludovicae*	0.061538	0.005917	0.042553
70	*Florisuga mellivora*	0.092308	0.000000	0.051672
70	*Heliodoxa imperatrix*	0.476923	0.031558	0.053191
70	*Heliodoxa rubinoides*	0.061538	0.031558	0.053191
70	*Ocreatus underwoodii*	0.123077	0.096515	0.054711
70	*Phaethornis syrmatophorus*	0.138462	0.030769	0.047112
70	*Thalurania colombica*	0.323077	0.000000	0.051672
70	*Urosticte benjamini*	0.061538	0.096515	0.054711
71	*Aglaeactis castelnaudii*	0.166667	0.000000	0.131148
71	*Aglaeactis cupripennis*	0.166667	0.363636	0.196721
71	*Colibri coruscans*	0.500000	0.000000	0.139344
71	*Oreonympha nobilis*	0.166667	0.000000	0.172131
71	*Oreotrochilus estella*	0.166667	0.000000	0.139344
71	*Pterophanes cyanopterus*	0.666667	0.636364	0.221311
72	*Anthracothorax nigricollis*	0.428571	0.166667	0.127273
72	*Campylopterus largipennis*	0.714286	0.166667	0.127273
72	*Florisuga mellivora*	0.285714	0.000000	0.118182
72	*Glaucis hirsutus*	0.428571	0.166667	0.127273
72	*Phaethornis hispidus*	0.428571	0.166667	0.127273
72	*Phaethornis ruber*	0.285714	0.166667	0.127273
72	*Thalurania furcata*	0.857143	0.166667	0.127273
72	*Threnetes leucurus*	0.428571	0.000000	0.118182
73	*Colibri thalassinus*	0.444444	0.000000	0.250000
73	*Eugenes fulgens*	0.500000	0.000000	0.250000
73	*Panterpe insignis*	0.777778	0.000000	0.250000
73	*Selasphorus flammula*	0.777778	0.000000	0.250000
74	*Colibri thalassinus*	0.280000	0.000000	0.159091
74	*Eugenes fulgens*	0.480000	0.000000	0.159091
74	*Lampornis castaneoventris*	0.160000	0.000000	0.204545
74	*Panterpe insignis*	0.440000	0.500000	0.238636
74	*Selasphorus flammula*	0.120000	0.500000	0.238636

CHAPTER 3



MORPHOLOGICAL AND EVOLUTIONARY EXTINCTION RISK SELECTIVITY IN HUMMINGBIRDS

Chapter formatted according to the requirements of *Biological Conservation*.

Morphological and evolutionary extinction risk selectivity in hummingbirds

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Extinction risk is a non-random condition and its selectivity may be associated with particular sets of morphological traits and evolutionary histories. The detection of attributes that are correlated with extinction risk is essential, since it can give insights about species vulnerability, mechanisms behind extinctions, mitigation of extinction drivers and impacts of species loss. Here we tested the occurrence of extinction risk selectivity in hummingbirds with particular morphological traits and evolutionary histories. We classified their extinction risk according to IUCN categorization. Among the 341 species of hummingbirds with sufficient data allowing categorization, we found that hummingbirds with short and straight bills and belonging to evolutionary common lineages have a higher extinction risk than hummingbirds with long and curved bills and belonging to distinct lineages. However, once phylogeny has been controlled, extinction

risk was independently associated with bill length and curvature. We also found that extinction risk was independently associated with wing chord and morphological distinctiveness. Our results showed that exclusive functions performed by hummingbirds with distinct morphologies and belonging to distinct lineages are less prone to extirpation, since there is no extinction risk selectivity associated with these traits. However, extinction risk selectivity on morphological traits may indirectly affect the integrity of interactions between hummingbirds and their nectar resources through the loss of keystone species, which are those with short and straight bills. Therefore, although IUCN categorization may be stressing the protection of keystone species, we suggest that conservation of hummingbirds should not be based solely on this categorization, since IUCN practices do not capture the morphological and evolutionary distinctiveness of the group.

Keywords: biological traits, conservation, evolutionary distinctiveness, IUCN Red List, morphological distinctiveness, threatened species.

1. INTRODUCTION

Extinction and extinction risk are non-random conditions (McKinney 1997). The selectivity of extinction is associated with different aspects of a species, like its morphological traits (Bennett and Owens 1997, Johnson et al. 2002, Jones et al. 2003, Olden et al. 2007) and evolutionary history (Purvis et al. 2000a, Fritz and Purvis 2010, Davies et al. 2011, Arregoitia et al. 2013). Under the current high rates of biodiversity loss (Barnosky et al. 2011), the detection of species attributes that are correlated with their extinction risk is of great importance. This information can give insights about mechanisms behind species extinctions (Fritz and Purvis 2010), help to predict the impacts of species loss over ecosystem functioning (Olden et al. 2007), mitigate the extinction drivers, prevent future

extinctions (Barnosky et al. 2011) and detect extinction vulnerability of certain species or clades (Fritz and Purvis 2010).

A growing body of studies indicates that traits related to body size may predispose species to the risk of extinction. For example, large-bodied birds (Bennett and Owens 1997) and marine fishes (Olden et al. 2007), as well as medium-sized marsupials have higher risk of extinction (Johnson et al. 2002). Also, bats with short and broad wings (Jones et al. 2003) and hawks with greater plumage polymorphisms (Krüger and Radford 2008) are more prone to extinction. Besides the selectivity associated with morphological traits, extinction risk may also be clumped into the evolutionary history of a group, with closely related species having similar extinction risk levels (Bennett and Owens 1997, Jones et al. 2003, Fritz and Purvis 2010). The clumping pattern of extinction risk distribution across the phylogeny may have a severe implication for biodiversity conservation, since the loss of threatened species could represent the loss of an entire evolutionary clade (Purvis et al. 2000a). Moreover, the impact of losing a clade is related to its evolutionary age and clade size (Isaac et al. 2007). Thus, the lost of older and species-poor clades is higher than younger and species-rich clades, because it would represent the complete loss of unique evolutionary history information (Crozier 1997). Therefore, recent conservation initiatives have highlighted the importance to protect these evolutionarily distinct species (Isaac et al. 2007, Cadotte and Davies 2010). However, the relation between species evolutionary distinctiveness and extinction risk is unclear, with either positive (Purvis et al. 2000a, Johnson et al. 2002, Redding and Mooers 2006, Arregoitia et al. 2013), negative (Davies et al. 2011) or no relation (Arregoitia et al. 2013) detected between these variables. On the other hand, extinction risk selectivity associated

with species morphological distinctiveness, which detects species with unique morphologies, has never being explored.

Hummingbirds tend to be the most specialized nectar-feeding birds in the world (Stiles 1981, Fleming and Muchhala 2008, Zanata et al. 2017). They perform an essential role in the reproduction of angiosperms through the Americas, pollinating more than 1,300 plant species (Arizmendi and Rodríguez-Flores 2012). The group can be split into nine evolutionary clades, according to their geographical region of origin (Bleiweiss 1998, McGuire et al. 2014). Among the 345 hummingbird species (Gill and Donsker 2014), 37 (11%) are classified under an extinction risk status and two are extinct: *Chlorostilbon bracei* (Lawrence, 1877) and *C. elegans* (Gould, 1860) (IUCN 2017). Small geographical range size is the major cause of extinction risk among the hummingbirds (n = 27; 73%), followed by small population size with a continuous declining (n = 15; 40%) and reductions in population size over the last 10 years (n = 8; 22%) (IUCN 2017).

The aim of this study was to test if the extinction risk of hummingbird species is associated with their morphological traits and evolutionary history. Specifically, we asked the following questions: Are morphological traits correlated with species extinction risk? Do morphologically distinct species have a higher extinction risk than morphologically common species? Is there a phylogenetic signal in the extinction risk and in the threat types of hummingbirds? Do evolutionary distinct lineages have a higher extinction risk than evolutionary common lineages?

2. MATERIAL AND METHODS

2.1 GLOBAL EXTINCTION RISK STATUS AND THREAT TYPES

To classify hummingbird species according to their global extinction risk status, we followed the standard classification of the International Union for Conservation of Nature (IUCN 2017). Hummingbird species were clumped in two groups according to their status by the IUCN: species ranked as vulnerable, endangered or critically endangered to extinction were classified as threatened, while species ranked as least concern or near threatened were classified as nonthreatened. We also obtained the threat types of each species from IUCN (2017) database (extinction risk status and threat types of each species can be found in the Appendix S2). Two extinct species, *Chlorostilbon bracei* (Lawrence, 1877) and *C. elegans* (Gould, 1860), and two species with deficient data to allow categorization of their extinction risk, *Discosura letitiae* (Bourcier & Mulsant, 1852) and *Heliangelus zusii* Graves, 1993 (IUCN 2017), were not included in the analyses.

2.2 MORPHOLOGICAL TRAITS

We tested the occurrence of extinction risk selectivity on three morphological traits of hummingbirds: bill length, bill curvature and wing chord, which are known to influence their interactions with nectar resources (Snow and Snow 1972, Temeles et al. 2002b, Zanata et al., *in prep.*, Chapter 1 and 2 of this thesis). Therefore, by evaluating the extinction selectivity associated with these morphological traits, it is also possible to infer its indirect effects on the plant community pollinated by hummingbirds. Morphological measurements were obtained from the inspection of 10 adult museum specimens of each species (details about the measurements can be found at the Appendix S3). Among the 341 extant species with sufficient data to allow categorization of their extinction risk status

by the IUCN (2017), morphological information was lacking for one nonthreatened species: *Chlorostilbon olivaresi* Stiles, 1996 and four threatened species: *Amazilia luciae* (Lawrence, 1868)*, Lepidopyga lilliae* Stone, 1917*, Lophornis brachylophus* Moore, 1949 and *Oxypogon stuebelii* Meyer, 1884, which represent 1% of extant species and 11% of threatened species (n = 37). Therefore, all morphological analyses were done with 336 species, including 33 threatened species.

2.3 MORPHOLOGICAL DISTINCTIVENESS

To detect morphologically distinct species of hummingbirds, we used the fair proportion index (Isaac et al. 2007). This index classifies each species by its morphological distinctiveness, through a weighted sum of the branch lengths from the root to the tip of each species in a morphological dendrogram. The weighting is done by dividing the branch length of each node by the number of species descending from that given node. The morphological dendrogram was built through a hierarchical clustering (UPGMA), using a Euclidian distance matrix of the standardized morphological traits. Therefore, greater values of morphological distinctiveness represent species with distinct morphologies, which may perform unique functions in the ecosystem (Isaac et al. 2007, Hidasi-Neto et al. 2015). We performed the calculations using the *evol.distinct* function from 'picante' 1.6-2 package (Kembel et al. 2010) in R (R Core Team, 2017).

2.4 PHYLOGENETIC DATA

Sixty hummingbird species (17%, Table S2 in Appendix S4) of the total extant hummingbird fauna (n = 343) (Gill and Donsker 2014) were not included in the most comprehensive dated phylogeny (McGuire et al. 2014). We inserted these missing species

using McGuire et al. (2014) phylogenetic hypothesis as a backbone phylogeny in the SUNPLIN software (Martins et al. 2013) (detailed insertion methods of missing species can be found in the Appendix S4). To deal with the phylogenetic uncertainty created by the insertion of the missing species, 1,000 fully resolved hypothetical phylogenies were generated. As a sensitivity analysis, all phylogenetic analyses described below were repeated 1,000 times using one of the 1,000 hypothetical phylogenies by time, to check the effect of the phylogenetic uncertainty on the results (Rangel et al. 2015).

2.5 PHYLOGENETIC SIGNAL

To test for the occurrence of a phylogenetic signal in extinction risk status and threat types of the 341 extant hummingbird species, we used the *D* index (Fritz and Purvis 2010). This index enables to detect if extinction risk or threat types are correlated with species evolutionary relatedness, by treating extinction risk and threat types as binary variables. Phylogenetic signal, described by phylogenetic clumping, is indicated by *D* values decreasing from one, while phylogenetic overdispersion is indicated by *D* values increasing from one. The significance of *D* values was tested against the mean of 1,000 simulated *D* values obtained under a random phylogenetic structure ($D = 1$) and under a Brownian evolutionary model ($D = 0$). In these simulations, *p*-values describe the probability of the observed *D* value result from a random or a Brownian phylogenetic structure (Fritz and Purvis 2010). We performed the calculation of the *D* index using the *phylo.d* function from 'caper' 0.5.2 package in R (Orme et al. 2013) in each one of the 1,000 hypothetical phylogenies.

2.6 EVOLUTIONARY DISTINCTIVENESS

To detect distinct lineages across the evolutionary history of hummingbirds, we used the fair proportion index (Isaac et al. 2007). This is the same index used to detect distinct morphologies, as described above. However, instead of using a morphological dendrogram, this analysis is done by using a phylogenetic tree. To classify each species by its evolutionary distinctiveness, this index combines evolutionary age and clade size, through a weighted sum of the branch lengths from the root to the tip of each species in a time-calibrated phylogeny. The weighting is done by dividing the branch length of each node by the number of species descending from that node. Therefore, greater values of evolutionary distinctiveness characterize species that belong to monotypic and species-poor clades in the phylogeny, which embody a large and unique phylogenetic information (Isaac et al. 2007). Evolutionary distinctiveness of each species was calculated across the 1,000 hypothetical phylogenies. We performed the calculations using the *evol.distinct* function from 'picante' 1.6-2 package in R (Kembel et al. 2010).

2.7 DETECTING EXTINCTION RISK SELECTIVITY

To detect extinction risk selectivity on morphological traits, as well as on morphological and evolutionary distinctiveness of hummingbirds, we first measured the observed mean value of each variable among the threatened species. Then, we performed 100,000 randomizations to measure the mean value of the given variable, by randomly including the same number of species as the number of threatened ones among all hummingbird species (n = 33 for morphological analyses and n = 37 for phylogenetic analyses). Finally, to detect the occurrence of an extinction risk selectivity in each variable, the probability (*p*) to obtain higher or lower values of the observed mean value across the mean values

obtained through the randomizations was calculated. To control the effect of evolutionary relatedness among species, we repeated the analyses by fixing the number of species selected in each evolutionary clade according to its number of threatened species (McGuire et al. 2014, IUCN 2017). Since we tested if the variables would be higher or lower than expected by chance among threatened species, the occurrence of an extinction risk selectivity was detected with $0.975 \leq p \leq 0.025$.

We conducted taxonomic adjustments, prior to analyses, as we followed the taxonomy proposed by Gill & Donsker (2014), while the IUCN (2017) follows the taxonomy proposed by del Hoyo et al. (2017). Details about these adjustments can be found in the Appendix S1.

3. RESULTS

Hummingbirds with higher extinction risk have shorter ($\mu_{threatened}$ = 17.40 and $\mu_{non\text{-}threatened}$ = 21.15, Fig. 1A) and more straight bills ($\mu_{threatened}$ = 0.00 and $\mu_{non\text{-}threatened}$ = 0.01, Fig. 1B) than expected by chance. However, no extinction risk selectivity was associated with wing chord ($\mu_{threatened}$ = 55.81 and $\mu_{non\text{-}threatened}$ = 56.36, Fig. 1C) or morphological distinctiveness of hummingbirds ($\mu_{threatened}$ = 0.15 and $\mu_{non\text{-}threatened}$ = 0.22, Fig. 1D, trait distribution among threatened and non-threatened species can be found at Appendix S5). Among the morphological more distinct hummingbirds (*i.e*. species with the 10% highest values of morphological distinctiveness, n = 34), only *Aglaeactis aliciae* Salvin, 1896 is threatened (Fig. 2; morphological distinctiveness values of each hummingbird species are available at Appendix S6). Once phylogeny has been controlled, hummingbirds with higher extinction risk still tends to have shorter and more straight bills. However, this relation is restricted within some evolutionary clades (Fig. 3).

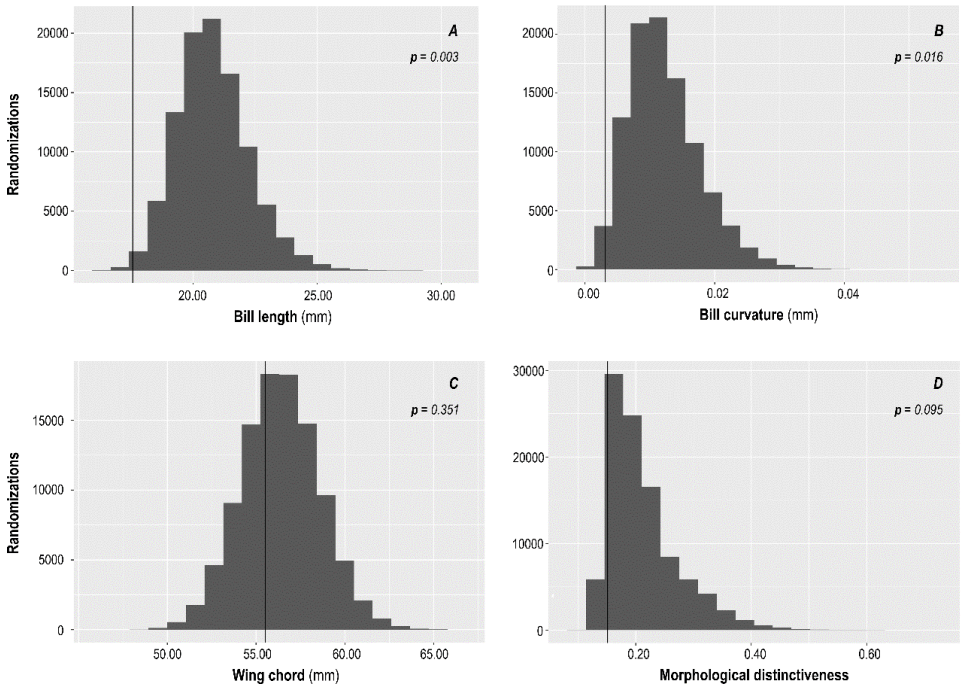

Fig. 1 – Extinction risk selectivity on the morphological features of hummingbirds. Lines represent the mean value of a given trait among the threatened species. Hummingbirds with short and straight bills have a higher extinction risk, as well as species wing chord and morphological distinctiveness is independently related with their extinction risk. Histograms represent the mean values obtained through 100,000 simulations by randomly choosing the same number of species as the number of threatened species (n = 33). *P*-values represent the probability to obtain equal or lower values than the mean value of a given trait of the threatened species across the simulations.

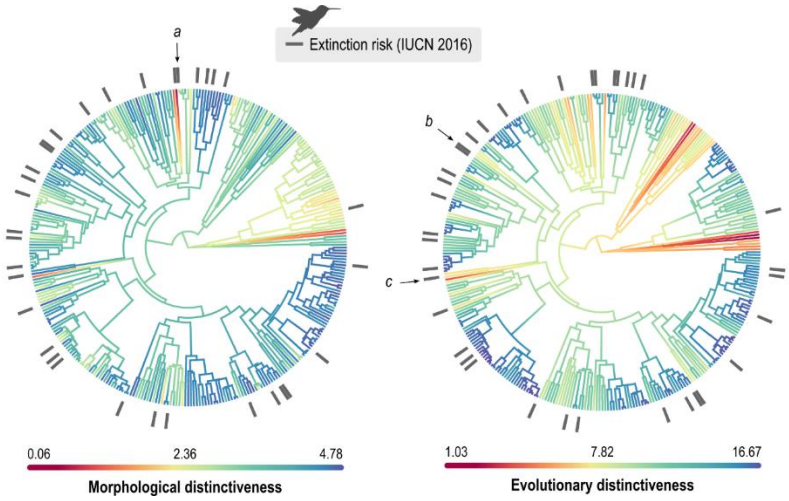

Fig. 2 – Distribution of morphological and evolutionary distinctiveness and extinction risk status of hummingbirds across their evolutionary history. Bars above phylogeny terminals represent threatened species. The evolutionary history is described by one of the 1,000 phylogenetic hypotheses used in the analysis, with McGuire et al. (2014) as a backbone phylogeny. Species with the 10% highest distinctiveness values and under an extinction risk status are highlighted in the figure: **a)** *Aglaeactis aliciae* Salvin, 1896; **b)** *Sephanoides fernandensis* (King, 1831); **c)** *Phlogophilus hemileucurus* Gould, 1860.

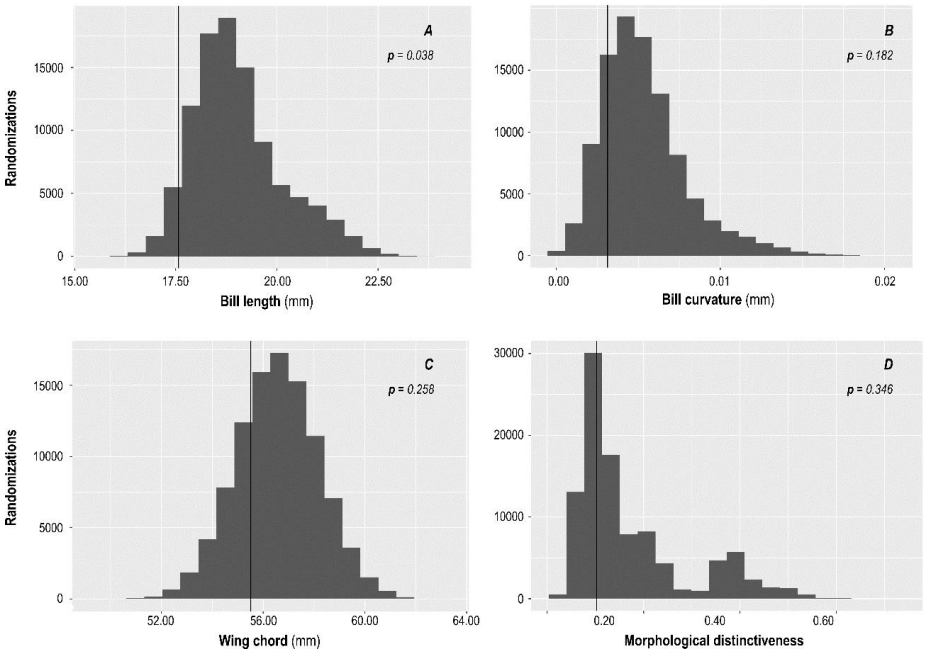

Fig. 3 – Extinction risk selectivity on the morphological features of hummingbirds, after controlling for phylogenetic relatedness. Lines representing the mean value of a given variable among the threatened species. Hummingbirds with short and straight bills tend to have higher extinction risk, as well as species wing chord and morphological distinctiveness is independently related with their extinction risk. Histograms representing the mean values obtained through 100,000 simulations by randomly choosing the same number of species as the number of threatened species (n = 33), while fixing the number of species selected among each evolutionary clade. *P*-values represent the probability to obtain equal or lower values than the mean value of a given variable of the threatened species across the simulations.

No phylogenetic signal was detected in extinction risk or threat types of hummingbirds, with extinction risk and threat types being randomly spread across the phylogenies and diverging from the clumping pattern expected under a Brownian phylogenetic structure (Table 1). Also, a weak effect of the phylogenetic uncertainty was detected in these results (Table 1). However, although no phylogenetic signal was detected in the extinction risk of hummingbirds, we identified some patterns at the clade-level, with Mangoes and Topazes having no threatened species and Hermits and Mountain Gems having only one threatened species, while Brilliants and Coquettes showed the highest proportion of threatened species (18% and 19%, respectively; Fig. 4). Additionally, evolutionary common lineages tended to show a higher extinction risk than evolutionary

distinct lineages (Fig. 5). However, a moderate effect of the phylogenetic uncertainty was detected in this relation (Fig. 5). Also, among the evolutionary more distinct hummingbirds (*i.e*. species with the 10% highest values of evolutionary distinctiveness, n = 34), only *Phlogophilus hemileucurus* Gould, 1860 and *Sephanoides fernandensis* (King, 1831) are threatened (Fig. 2; evolutionary distinctiveness values of each hummingbird species are available at Appendix S6).

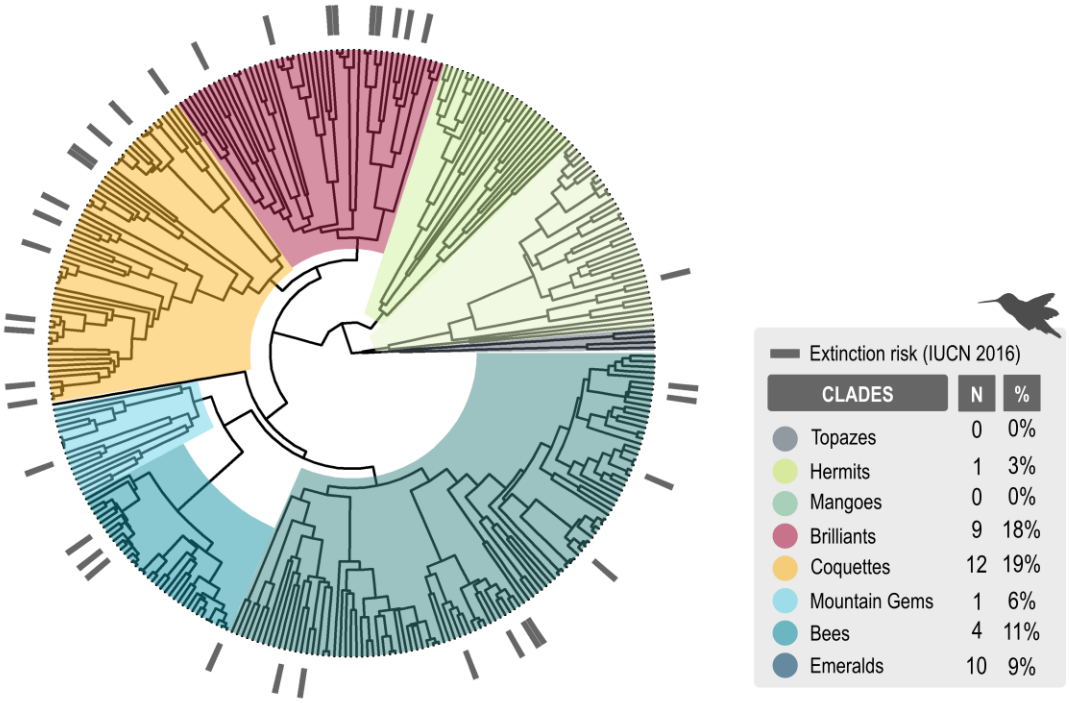

Fig. 4 – Distribution of the extinction risk of hummingbirds across their evolutionary history, with different colours representing different evolutionary clades (McGuire et al. 2014). Bars above phylogeny terminals represent threatened species. Extinction risk tends to be clumped within the clades of Brilliants and Coquettes. The evolutionary history is described by one of the 1,000 phylogenetic hypotheses used in the analyses, with McGuire et al. (2014) as a backbone phylogeny. **N –** number of threatened species in each clade; **% –** proportion of threatened species in relation to the total number of species in each clade.

Table 1 – Phylogenetic signal (*D*) in the extinction risk and in the threat types of 341 extant hummingbird species. *D* and *p*-values obtained by the repetition of the analysis, using one of the 1,000 phylogenetic hypotheses by time. *P*-values describe the probability of the observed *D* value result from a random or a Brownian phylogenetic structure. In parenthesis, the effect of the phylogenetic uncertainty in the results, described the proportion of *p*-values $\leq$ 0.05 obtained among the 1,000 phylogenetic hypotheses analyzed by time.

	D $\mu \pm \sigma$	***p*-Random** range	***p*-Brownian** range
Extinction risk	0.95 ± 0.03	0.66 – 0.03 (0.005)	0.00 – 0.00 (1.000)
Threat type			
Reduction in population size	0. 89 ± 0.07	0.72 – 0.04 (0.002)	0.05 – 0.00 (1.000)
Small geographical range	0.86 ± 0.04	0.34 – 0.00 (0.020)	0.00 – 0.00 (1.000)
Small population size	1.04 ± 0.07	0.96 – 0.07 (0.000)	0.01 – 0.00 (1.000)

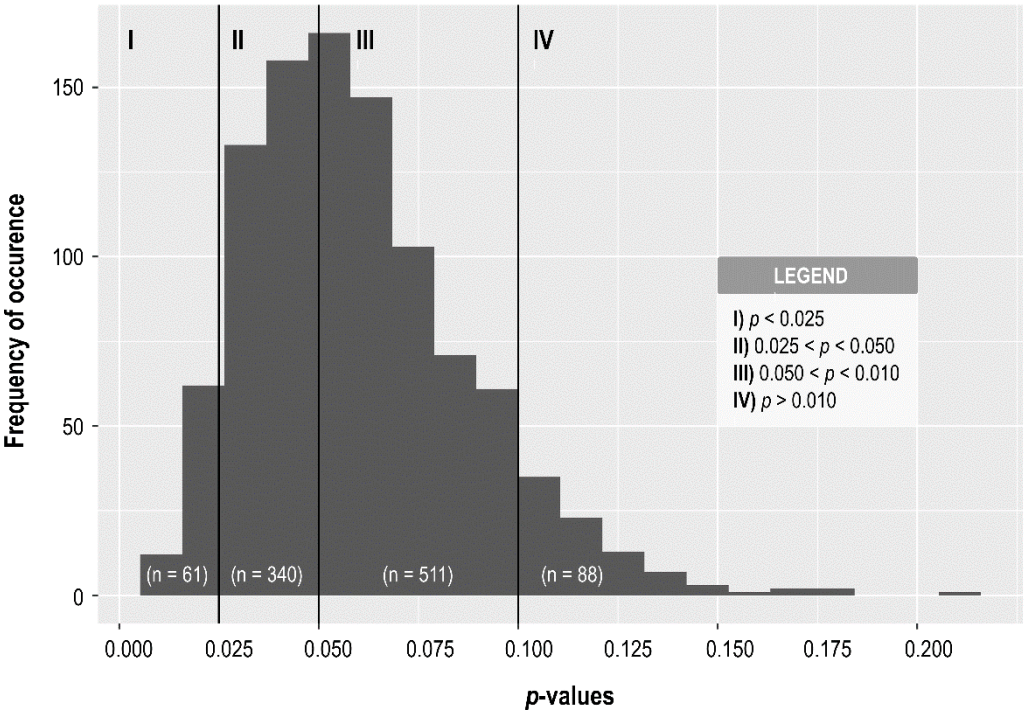

Fig. 5 – Extinction risk selectivity on the evolutionary distinctiveness of hummingbirds. Frequency of occurrence of *p*-values obtained in each one of the 1,000 phylogenetic hypotheses analyzed, describing the phylogenetic uncertainty in the results. *P*-values represent the probability to obtain equal or lower values than the mean value of evolutionary distinctiveness of the threatened species across 100,000 randomizations.

4. DISCUSSION

We detected an extinction risk selectivity on the morphological traits and evolutionary history of hummingbirds. Specifically, we found that hummingbirds with short and straight bills have a higher extinction risk than hummingbirds with long and curved bills. However, this relation is restricted within some evolutionary clades. Also, evolutionary common lineages tend to have a higher extinction risk than evolutionary distinct lineages.

The relation detected between bill length and bill curvature and the extinction risk of hummingbirds stresses a vulnerability for the integrity of interactions between these birds and their nectar resources, since keystone species in plant-hummingbird networks tend also to have short and straight bills (Zanata et al., *in prep.*, Chapter 2 of this thesis). Therefore, keystone roles performed by these hummingbirds may also be vulnerable to extirpation. However, while controlling for species evolutionary relatedness, we detected that the relation between bill morphologies and extinction risk of hummingbirds were lost. We suggest that it may occur because bill length and bill curvature may have a phylogenetic signal (Münkemüller et al. 2012), with closely related species having bills with similar lengths and curvatures. Therefore, since a higher proportion of threatened species is clumped into the evolutionary clades of Brilliants and Coquettes, which are composed by hummingbirds that tend to have short and straight bills (del Hoyo et al. 2017b), the relation between bill morphology and extinction risk may be affected while controlling for species evolutionary relatedness. Among other morphological traits analyzed, we also found that extinction risk was independently associated with wing chord. This result diverges from expected, since wing chord may be correlated with body size, a morphological feature that tend to be related to extinction risk selectivity in different taxonomic groups, like fishes, mammals and other bird taxa (Bennett and Owens 1997,

Johnson et al. 2002, Jones et al. 2003, Olden et al. 2007). Moreover, we also found that extinction risk was independently associated with species morphological distinctiveness. Therefore, species with distinct morphologies are not under a higher extinction risk than species with common morphologies. This result highlights a robustness to plant-hummingbird interactions, since morphological distinct hummingbird species tend to be the exclusive pollinators of particular sets of plant species (Zanata et al., *in prep.*, Chapter 1 of this thesis).

The uncoupled relation between extinction risk and threat types of hummingbirds and its evolutionary relatedness diverges from the positive relation detected for other vertebrate groups, like mammals and other bird taxa (Bennett and Owens 1997, Jones et al. 2003, Fritz and Purvis 2010). However, since the major extinction threats of hummingbirds are their small geographical range size and small population size, which tend not to be associated with species evolutionary relatedness (Diniz-Filho and Tôrres 2002, Vereecken 2017), may explain why extinction risk is independent from species relatedness. Therefore, the absence of phylogenetic signal in extinction risk and threat types of hummingbirds indicate that the mechanisms behind species extinction may be related with other biological attributes that are more evolutionarily labile, or that extinction risk is a result of different local extinction pressures, which are not reflected in their evolutionary history (Fritz and Purvis 2010). However, although we did not find a phylogenetic signal in the extinction risk and threat types of hummingbirds, the pattern found at the clade-level showed that extinction risk tends to be clumped within the clades of Brilliants and Coquettes, which may have a higher extinction susceptibility than the remainder clades. This higher susceptibility may be related with their tendency to have small geographical range sizes (McGuire et al. 2014, IUCN 2017), the major threat among

hummingbirds (Table S1 in Appendix S2; IUCN, 2017). However, the clumped distribution of extinction risk in the evolutionary history of hummingbirds may represent an additional risk for their conservation, since the loss of threatened species could lead to a substantial loss of species within specific evolutionary clades (Purvis et al. 2000a).

The negative relation found between evolutionary distinctiveness and extinction risk, with common lineages having higher extinction risk than distinct lineages has been already described for plants (Davies et al. 2011). However, this is the first time that it was detected for animals, where a positive relation tends to be the most common pattern (Purvis et al. 2000a, Johnson et al. 2002, Redding and Mooers 2006, Arregoitia et al. 2013). Moreover, this negative relation between species evolutionary distinctiveness and extinction risk stresses a robustness to plant-hummingbird interactions, since hummingbird species belonging to distinct lineages tend also to be the exclusive pollinators of some plant species (Zanata et al., *in prep.*, Chapter 1 of this thesis). Therefore, exclusive functions performed by hummingbirds belonging to distinct lineages may be protected to extirpation. Also, in order to prevent the loss of a disproportionately large amount of morphological and evolutionary information in the near future, we highlight the need of higher conservation priority for three species: *Aglaeactis aliciae* Salvin, 1986, *Phlogophilus hemileucurus* Gould, 1860 and *Sephanoides fernandensis* (King, 1831), since these are the most distinct threatened hummingbird species. However, this result, where only three species among those with the 10% highest values of distinctiveness are threatened, as well as the extinction risk being either non-related to morphological distinctiveness and negatively related to evolutionary distinctiveness, suggest a conservation vulnerability. These results combined highlight that hummingbird conservation based solely on IUCN recommendations is not capturing morphological and

evolutionary distinctiveness of the group. Therefore, if the conservation of distinct morphological and evolutionary information is intended, in order to protect non-redundant species in the tree of life, the inclusion of species morphological and evolutionary distinctiveness information in conservation practices is essential (Redding and Mooers 2006, Isaac et al. 2007, Vereecken 2017).

5. CONCLUSION

We detected an extinction risk selectivity on morphological traits and evolutionary history of hummingbirds. This selectivity may indirectly affect the integrity of interactions between hummingbirds and their nectar resources by the extirpation of keystone species. However, the exclusive functions performed by hummingbirds with distinct morphologies and belonging to distinct lineages are less vulnerable to extirpation, since there is no extinction risk selectivity on these traits. Also, we suggest that the conservation of hummingbirds should not be based solely on IUCN recommendations, since their practices do not capture the morphological and evolutionary distinctiveness of the group.

SUPPLEMENTARY MATERIAL

APPENDIX S1 – Taxonomic adjustments

APPENDIX S2 – Extinction risk status, threat type and evolutionary clade of hummingbirds

APPENDIX S3 – Morphological traits measurements

APPENDIX S4 – Insertion methods of species missing in the phylogeny of McGuire et al. (2014)

APPENDIX S5 – Trait distribution among threatened and non-threatened hummingbird species

APPENDIX S6 – Morphological and evolutionary distinctiveness of hummingbirds

ACKNOWLEDGEMENTS

We thank Guilherme D. S. Seger for his help with the analysis.

FUNDING

This study was funded by CAPES Foundation (PDSE scholarship proc. 8105/2014-6), MCTI/CNPQ/UNIVERSAL (proc. 445405/2014-7), the Center for Macroecology, Evolution and Climate (CMEC) and the Danish Council for Independent Research Natural Sciences.

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7. SUPPLEMENTARY MATERIAL

APPENDIX S1 – TAXONOMIC ADJUSTMENTS

Four species recognized by Gill & Donsker (2014) are classified as subspecies by del Hoyo et al. (2016): *Campylopterus excellens*, *Campylopterus pampa*, *Chlorostilbon alice* and *Chlorostilbon melanorhynchus*. Then, we classified the extinction risk of these species according to the extinction risk status of the species they belong: *Campylopterus curvipennis* (both *C. excellens* and *C. pampa*), *Chlorostilbon poortmani* and *Chlorostilbon mellisugus*, according to del Hoyo et al. (2016). Also, twenty-four species recognized by del Hoyo et al. (2016) are classified as subspecies by Gill & Donsker (2014): *Amazilia bartletti, Amazilia cupreicauda, Anthracothorax aurulentus, Coeligena albicaudata, Coeligena conradii, Coeligena consita, Coeligena dichroura, Coeligena eisenmanni, Coeligena eos, Coeligena inca, Coeligena osculans, Cynanthus lawrencei, Eriocnemis sapphiropygia, Heliangelus clarisse, Heliangelus spencei, Heliodoxa whitelyana, Lophornis verreauxii, Oreonympha albolimbata, Oreotrochilus stolzmanni, Phaethornis baroni, Phaethornis porcullae, Schistes albogularis, Stephanoxis loddigesii* and *Urochroa leucura*. However, there is no difference between the extinction risk status if these species and the species they belong according to Gill & Donsker (2014), with the exception of *Coeligena consita*, which is classified as vulnerable to extinction, while the species its belong, *Coeligena bonapartei* (Gill & Donsker 2014), is classified as least concern to extinction (IUCN 2016).

APPENDIX S2 – EXTINCTION RISK STATUS, THREAT TYPE AND EVOLUTIONARY CLADE OF HUMMINGBIRD SPECIES

Table S1 – Extinction risk status, threat type (IUCN 2016) and evolutionary clade (Bleiwess 1998, McGuire et al. 2014) of each hummingbird species.

Species	Extinction risk status	Threat type	Clade
Abeillia abeillei	Least concern	-	Em
Adelomyia melanogenys	Least concern	-	Co
Aglaeactis aliciae	Endangered	C	Br
Aglaeactis castelnaudii	Least concern	-	Br
Aglaeactis cupripennis	Least concern	-	Br
Aglaeactis pamela	Least concern	-	Br
Aglaiocercus berlepschi	Endangered	B	Co
Aglaiocercus coelestis	Least concern	-	Co
Aglaiocercus kingii	Least concern	-	Co
Amazilia amabilis	Least concern	-	Em
Amazilia amazilia	Least concern	-	Em
Amazilia beryllina	Least concern	-	Em
Amazilia boucardi	Endangered	B	Em
Amazilia brevirostris	Least concern	-	Em
Amazilia candida	Least concern	-	Em
Amazilia castaneiventris	Endangered	B	Em
Amazilia chionogaster	Least concern	-	Em
Amazilia cyanifrons	Least concern	-	Em
Amazilia cyanocephala	Least concern	-	Em
Amazilia cyanura	Least concern	-	Em
Amazilia decora	Least concern	-	Em
Amazilia edward	Least concern	-	Em
Amazilia fimbriata	Least concern	-	Em
Amazilia franciae	Least concern	-	Em
Amazilia lactea	Least concern	-	Em
Amazilia leucogaster	Least concern	-	Em
Amazilia luciae	Endangered	B, C	Em
Amazilia rosenbergi	Least concern	-	Em
Amazilia rutila	Least concern	-	Em
Amazilia saucerottei	Least concern	-	Em
Amazilia tobaci	Least concern	-	Em
Amazilia tzacatl	Least concern	-	Em
Amazilia versicolor	Least concern	-	Em
Amazilia violiceps	Least concern	-	Em
Amazilia viridicauda	Least concern	-	Em
Amazilia viridifrons	Least concern	-	Em
Amazilia viridigaster	Least concern	-	Em
Amazilia wagneri	Least concern	-	Em

Amazilia yucatanensis	Least concern	-	Em
Androdon aequatorialis	Least concern	-	Ma
Anopetia gounellei	Least concern	-	He
Anthocephala floriceps	Vulnerable	B	Em
Anthracothorax dominicus	Least concern	-	Ma
Anthracothorax mango	Least concern	-	Ma
Anthracothorax nigricollis	Least concern	-	Ma
Anthracothorax prevostii	Least concern	-	Ma
Anthracothorax veraguensis	Least concern	-	Ma
Anthracothorax viridigula	Least concern	-	Ma
Anthracothorax viridis	Least concern	-	Ma
Aphantochroa cirrochloris	Least concern	-	Em
Archilochus alexandri	Least concern	-	Be
Archilochus colubris	Least concern	-	Be
Atthis ellioti	Least concern	-	Be
Atthis heloisa	Least concern	-	Be
Augastes lumachella	Near threatened	-	Ma
Augastes scutatus	Near threatened	-	Ma
Avocettula recurvirostris	Least concern	-	Ma
Basilinna leucotis	Least concern	-	Em
Basilinna xantusii	Least concern	-	Em
Boissonneaua flavescens	Least concern	-	Br
Boissonneaua jardini	Least concern	-	Br
Boissonneaua matthewsii	Least concern	-	Br
Calliphlox amethystina	Least concern	-	Be
Calliphlox bryantae	Least concern	-	Be
Calliphlox evelynae	Least concern	-	Be
Calliphlox mitchellii	Least concern	-	Be
Calothorax lucifer	Least concern	-	Be
Calothorax pulcher	Least concern	-	Be
Calypte anna	Least concern	-	Be
Calypte costae	Least concern	-	Be
Campylopterus curvipennis	Least concern	-	Em
Campylopterus duidae	Least concern	-	Em
Campylopterus ensipennis	Near threatened	-	Em
Campylopterus excellens	Least concern	-	Em
Campylopterus falcatus	Least concern	-	Em
Campylopterus hemileucurus	Least concern	-	Em
Campylopterus hyperythrus	Least concern	-	Em
Campylopterus largipennis	Least concern	-	Em
Campylopterus pampa	Least concern	-	Em
Campylopterus phainopeplus	Endangered	B	Em
Campylopterus rufus	Least concern	-	Em
Campylopterus villaviscensio	Near threatened	-	Em
Chaetocercus astreans	Least concern	-	Be
Chaetocercus berlepschi	Endangered	A, B, C	Be

Chaetocercus bombus	Vulnerable	C	Be
Chaetocercus heliodor	Least concern	-	Be
Chaetocercus jourdanii	Least concern	-	Be
Chaetocercus mulsant	Least concern	-	Be
Chalcostigma herrani	Least concern	-	Co
Chalcostigma heteropogon	Least concern	-	Co
Chalcostigma olivaceum	Least concern	-	Co
Chalcostigma ruficeps	Least concern	-	Co
Chalcostigma stanleyi	Least concern	-	Co
Chalybura buffonii	Least concern	-	Em
Chalybura urochrysia	Least concern	-	Em
Chlorestes notata	Least concern	-	Em
Chlorostilbon alice	Least concern	-	Em
Chlorostilbon assimilis	Least concern	-	Em
Chlorostilbon auriceps	Least concern	-	Em
Chlorostilbon bracei	Extinct	-	Em
Chlorostilbon canivetii	Least concern	-	Em
Chlorostilbon elegans	Extinct	-	Em
Chlorostilbon forficatus	Least concern	-	Em
Chlorostilbon gibsoni	Least concern	-	Em
Chlorostilbon lucidus	Least concern	-	Em
Chlorostilbon maugaeus	Least concern	-	Em
Chlorostilbon melanorhynchus	Least concern	-	Em
Chlorostilbon mellisugus	Least concern	-	Em
Chlorostilbon olivaresi	Least concern	-	Em
Chlorostilbon poortmani	Least concern	-	Em
Chlorostilbon ricordii	Least concern	-	Em
Chlorostilbon russatus	Least concern	-	Em
Chlorostilbon stenurus	Least concern	-	Em
Chlorostilbon swainsonii	Least concern	-	Em
Chrysolampis mosquitus	Least concern	-	Ma
Chrysuronia oenone	Least concern	-	Em
Clytolaema rubricauda	Least concern	-	Br
Coeligena bonapartei	Least concern	-	Br
Coeligena	Least concern	-	Br
Coeligena helianthea	Least concern	-	Br
Coeligena iris	Least concern	-	Br
Coeligena lutetiae	Least concern	-	Br
Coeligena orina	Critically endangered	B, C	Br
Coeligena phalerata	Least concern	-	Br
Coeligena prunellei	Vulnerable	B, C	Br
Coeligena torquata	Least concern	-	Br
Coeligena violifer	Least concern	-	Br
Coeligena wilsoni	Least concern	-	Br
Colibri coruscans	Least concern	-	Ma
Colibri delphinae	Least concern	-	Ma

Colibri serrirostris	Least concern	-	Ma
Colibri thalassinus	Least concern	-	Ma
Cyanophaia bicolor	Least concern	-	Em
Cynanthus doubledayi	Least concern	-	Em
Cynanthus latirostris	Least concern	-	Em
Cynanthus sordidus	Least concern	-	Em
Damophila julie	Least concern	-	Em
Discosura conversii	Least concern	-	Co
Discosura langsdorffi	Least concern	-	Co
Discosura letitiae	Data deficient	-	Co
Discosura longicaudus	Least concern	-	Co
Discosura popelairii	Near threatened	-	Co
Doricha eliza	Near threatened	-	Be
Doricha enicura	Least concern	-	Be
Doryfera johannae	Least concern	-	Ma
Doryfera ludovicae	Least concern	-	Ma
Elvira chionura	Least concern	-	Em
Elvira cupreiceps	Least concern	-	Em
Ensifera ensifera	Least concern	-	Br
Eriocnemis aline	Least concern	-	Br
Eriocnemis cupreoventris	Near threatened	-	Br
Eriocnemis derbyi	Near threatened	-	Br
Eriocnemis glaucopoides	Least concern	-	Br
Eriocnemis godini	Critically endangered	D	Br
Eriocnemis isabellae	Critically endangered	B	Br
Eriocnemis luciani	Least concern	-	Br
Eriocnemis mirabilis	Critically endangered	B	Br
Eriocnemis mosquera	Least concern	-	Br
Eriocnemis nigrivestis	Critically endangered	B	Br
Eriocnemis vestita	Least concern	-	Br
Eugenes fulgens	Least concern	-	Mt
Eulampis holosericeus	Least concern	-	Ma
Eulampis jugularis	Least concern	-	Ma
Eulidia yarrellii	Critically endangered	A	Be
Eupetomena macroura	Least concern	-	Em
Eupherusa cyanophrys	Endangered	B	Em
Eupherusa eximia	Least concern	-	Em
Eupherusa nigriventris	Least concern	-	Em
Eupherusa poliocerca	Vulnerable	A, B	Em
Eutoxeres aquila	Least concern	-	He
Eutoxeres condamini	Least concern	-	He
Florisuga fusca	Least concern	-	To
Florisuga mellivora	Least concern	-	To
Glaucis aeneus	Least concern	-	He
Glaucis dohrnii	Endangered	B, C	He
Glaucis hirsutus	Least concern	-	He

Goethalsia bella	Near threatened	-	Em
Goldmania violiceps	Least concern	-	Em
Haplophaedia assimilis	Least concern	-	Br
Haplophaedia aureliae	Least concern	-	Br
Haplophaedia lugens	Near threatened	-	Br
Heliactin bilophus	Least concern	-	Ma
Heliangelus amethysticollis	Least concern	-	Co
Heliangelus exortis	Least concern	-	Co
Heliangelus mavors	Least concern	-	Co
Heliangelus micraster	Least concern	-	Co
Heliangelus regalis	Endangered	A, B	Co
Heliangelus strophianus	Least concern	-	Co
Heliangelus viola	Least concern	-	Co
Heliangelus zusii	Data deficient	-	Co
Heliodoxa aurescens	Least concern	-	Br
Heliodoxa branickii	Least concern	-	Br
Heliodoxa gularis	Vulnerable	A	Br
Heliodoxa imperatrix	Least concern	-	Br
Heliodoxa jacula	Least concern	-	Br
Heliodoxa leadbeateri	Least concern	-	Br
Heliodoxa rubinoides	Least concern	-	Br
Heliodoxa schreibersii	Least concern	-	Br
Heliodoxa xanthogonys	Least concern	-	Br
Heliomaster constantii	Least concern	-	Mt
Heliomaster furcifer	Least concern	-	Mt
Heliomaster longirostris	Least concern	-	Mt
Heliomaster squamosus	Least concern	-	Mt
Heliothryx auritus	Least concern	-	Ma
Heliothryx barroti	Least concern	-	Ma
Hylocharis chrysura	Least concern	-	Em
Hylocharis cyanus	Least concern	-	Em
Hylocharis eliciae	Least concern	-	Em
Hylocharis grayi	Least concern	-	Em
Hylocharis humboldtii	Least concern	-	Em
Hylocharis sapphirina	Least concern	-	Em
Hylonympha macrocerca	Endangered	B	Mt
Klais guimeti	Least concern	-	Em
Lafresnaya lafresnayi	Least concern	-	Br
Lampornis amethystinus	Least concern	-	Mt
Lampornis calolaemus	Least concern	-	Mt
Lampornis castaneoventris	Least concern	-	Mt
Lampornis cinereicauda	Least concern	-	Mt
Lampornis clemenciae	Least concern	-	Mt
Lampornis hemileucus	Least concern	-	Mt
Lampornis sybillae	Least concern	-	Mt
Lampornis viridipallens	Least concern	-	Mt

Lamprolaima rhami	Least concern	-	Mt
Lepidopyga coeruleogularis	Least concern	-	Em
Lepidopyga goudoti	Least concern	-	Em
Lepidopyga lilliae	Critically endangered	C	Em
Lesbia nuna	Least concern	-	Co
Lesbia victoriae	Least concern	-	Co
Leucippus baeri	Least concern	-	Em
Leucippus chlorocercus	Least concern	-	Em
Leucippus fallax	Least concern	-	Em
Leucippus taczanowskii	Least concern	-	Em
Leucochloris albicollis	Least concern	-	Em
Loddigesia mirabilis	Endangered	A, B, C	Br
Lophornis adorabilis	Least concern	-	Co
Lophornis brachylophus	Critically endangered	B	Co
Lophornis chalybeus	Near threatened	-	Co
Lophornis delattrei	Least concern	-	Co
Lophornis gouldii	Vulnerable	A	Co
Lophornis helenae	Least concern	-	Co
Lophornis magnificus	Least concern	-	Co
Lophornis ornatus	Least concern	-	Co
Lophornis pavoninus	Least concern	-	Co
Lophornis stictolophus	Least concern	-	Co
Mellisuga helenae	Near threatened	-	Be
Mellisuga minima	Least concern	-	Be
Metallura aeneocauda	Least concern	-	Co
Metallura baroni	Endangered	B	Co
Metallura eupogon	Least concern	-	Co
Metallura iracunda	Endangered	B	Co
Metallura odomae	Least concern	-	Co
Metallura phoebe	Least concern	-	Co
Metallura theresiae	Least concern	-	Co
Metallura tyrianthina	Least concern	-	Co
Metallura williami	Least concern	-	Co
Microchera albocoronata	Least concern	-	Em
Microstilbon burmeisteri	Least concern	-	Be
Myrmia micrura	Least concern	-	Be
Myrtis fanny	Least concern	-	Be
Ocreatus underwoodii	Least concern	-	Br
Opisthoprora euryptera	Least concern	-	Co
Oreonympha nobilis	Least concern	-	Co
Oreotrochilus adela	Near threatened	-	Co
Oreotrochilus chimborazo	Least concern	-	Co
Oreotrochilus estella	Least concern	-	Co
Oreotrochilus leucopleurus	Least concern	-	Co
Oreotrochilus melanogaster	Least concern	-	Co
Orthorhyncus cristatus	Least concern	-	Em

Oxypogon cyanolaemus	Critically endangered	C	Co
Oxypogon guerinii	Least concern	-	Co
Oxypogon lindenii	Least concern	-	Co
Oxypogon stuebelii	Vulnerable	D	Co
Panterpe insignis	Least concern	-	Mt
Patagona gigas	Least concern	-	Pa
Phaeochroa cuvierii	Least concern	-	Em
Phaethornis aethopygus	Near threatened	-	He
Phaethornis anthophilus	Least concern	-	He
Phaethornis atrimentalis	Least concern	-	He
Phaethornis augusti	Least concern	-	He
Phaethornis bourcieri	Least concern	-	He
Phaethornis eurynome	Least concern	-	He
Phaethornis griseogularis	Least concern	-	He
Phaethornis guy	Least concern	-	He
Phaethornis hispidus	Least concern	-	He
Phaethornis idaliae	Least concern	-	He
Phaethornis koepckeae	Near threatened	-	He
Phaethornis longirostris	Least concern	-	He
Phaethornis longuemareus	Least concern	-	He
Phaethornis malaris	Least concern	-	He
Phaethornis mexicanus	Least concern	-	He
Phaethornis nattereri	Least concern	-	He
Phaethornis philippii	Least concern	-	He
Phaethornis pretrei	Least concern	-	He
Phaethornis ruber	Least concern	-	He
Phaethornis rupurumii	Least concern	-	He
Phaethornis squalidus	Least concern	-	He
Phaethornis striigularis	Least concern	-	He
Phaethornis stuarti	Least concern	-	He
Phaethornis subochraceus	Least concern	-	He
Phaethornis superciliosus	Least concern	-	He
Phaethornis syrmatophorus	Least concern	-	He
Phaethornis yaruqui	Least concern	-	He
Phlogophilus harterti	Near threatened	-	Co
Phlogophilus hemileucurus	Vulnerable	A	Co
Polyonymus caroli	Least concern	-	Co
Polytmus guainumbi	Least concern	-	Ma
Polytmus milleri	Least concern	-	Ma
Polytmus theresiae	Least concern	-	Ma
Pterophanes cyanopterus	Least concern	-	Br
Ramphodon naevius	Near threatened	-	He
Ramphomicron dorsale	Endangered	B	Co
Ramphomicron microrhynchum	Least concern	-	Co
Rhodopis vesper	Least concern	-	Be
Sappho sparganurus	Least concern	-	Co

Schistes geoffroyi	Least concern	-	Ma
Selasphorus ardens	Endangered	C	Be
Selasphorus calliope	Least concern	-	Be
Selasphorus flammula	Least concern	-	Be
Selasphorus platycercus	Least concern	-	Be
Selasphorus rufus	Least concern	-	Be
Selasphorus sasin	Least concern	-	Be
Selasphorus scintilla	Least concern	-	Be
Sephanoides fernandensis	Critically endangered	B	Co
Sephanoides sephaniodes	Least concern	-	Co
Stephanoxis lalandi	Least concern	-	Em
Sternoclyta cyanopectus	Least concern	-	Mt
Taphrolesbia griseiventris	Endangered	B, C	Co
Taphrospilus hypostictus	Least concern	-	Co
Thalurania colombica	Least concern	-	Em
Thalurania furcata	Least concern	-	Em
Thalurania glaucopis	Least concern	-	Em
Thalurania ridgwayi	Vulnerable	B	Em
Thalurania watertonii	Endangered	B, C	Em
Thaumastura cora	Least concern	-	Be
Threnetes leucurus	Least concern	-	He
Threnetes niger	Least concern	-	He
Threnetes ruckeri	Least concern	-	He
Tilmatura dupontii	Least concern	-	Be
Topaza pella	Least concern	-	To
Topaza pyra	Least concern	-	To
Trochilus polytmus	Least concern	-	Em
Trochilus scitulus	Least concern	-	Em
Urochroa bougueri	Least concern	-	Br
Urosticte benjamini	Least concern	-	Br
Urosticte ruficrissa	Least concern	-	Br

A – reduction in population size; B – small geographical range; Be – bees; Br – brilliants; C – small population size; Co – coquettes; Em – emeralds; He – hermits; Ma – mangoes; Mt – mountain gems; Pa – patagona; To – topazes

APPENDIX S3 – MORPHOLOGICAL TRAITS MEASUREMENTS

The morphological measurements were done through the inspection of museum specimens. Where possible, we measured 10 adult specimens of each species, except for *Amazilia luciae* (n = 1), *Coeligena orina* (n = 1), *Discosura letitiae* (n = 1), *Amazilia wagneri* (n = 2), *Eriocnemis mirabilis* (n = 2), *Leucippus baeri* (n = 2), *Ramphomicron dorsale* (n = 2), *Metallura odomae* (n = 3), *Chaetocercus astreans* (n = 4), *Heliangelus regalis* (n = 4), *Amazilia brevirostris* (n = 5), *Goethalsia bella* (n = 5), *Amazilia castaneiventris* (n = 6), *Campylopterus excellens* (n = 6), *Campylopterus pampa* (n = 6), *Eriocnemis godini* (n = 7), *Heliodoxa gularis* (n = 7), *Phaethornis subochraceus* (n = 7), *Thalurania ridgwayi* (n = 7), *Thalurania watertonii* (n = 7) and *Selasphorus ardens* (n = 8). To include possible sexual dimorphism, also, where possible, we measured five females and five males of each species. We were able to do this for 243 species, corresponding to 71% species of our dataset. To avoid intraspecific variation, we measured specimens belonging to the same subspecies or collected from the same site. In total, we have measured 1,584 specimens belonging to 158 species, according to the IOC World Bird list (version 4.4, Gill & Donsker 2014). The specimens were inspected in the following museums: American Museum of Natural History (AMNH – USA), Field Museum of Natural History (FMNH – USA), Museu de Biologia Professor Mello Leitão (MBML – Brazil), Museu Nacional (MNRJ –Brazil), Museu Paraense Emílio Goeldi (MPEG – Brazil), Natural History Museum at Tring (NHMT – United Kingdom), Senckenberg Naturmuseum Frankfurt (SMF – Germany), Smithsonian National Museum of Natural History (USNM – USA), Zoologisches Forschungsmuseum Alexander Koenig (ZFMK – Germany) and Zoologisk Museum, Statens

Naturhistoriske Museum (ZMSNM – Denmark). The list of inspected specimens in each museum can be found below (Table S2).

Wing chord was measured from the carpal joint to the tip of the longest primary feather on unflatten wing of the right side, using a digital calliper with a precision to the nearest 0.01 mm.

Bill measurements were done through digital photographs of the right lateral view of the specimens and were conducted on the software ImageJ (Schneider et al. 2012). Each photograph included a ruler, as a scale reference for the measurements. To avoid image distortions, the camera was positioned perpendicular to the right-sagittal plane of the bill and distant around 15 cm of the specimen. To guarantee that the bill was parallel to the surface, we placed the specimen on a foam base using pins as an external support, to not damage the skins.

Bill length described the chord of the exposed culmen, measured as the linear distance from bill tip to the anterior extension of feathers (in mm, Fig. S1).

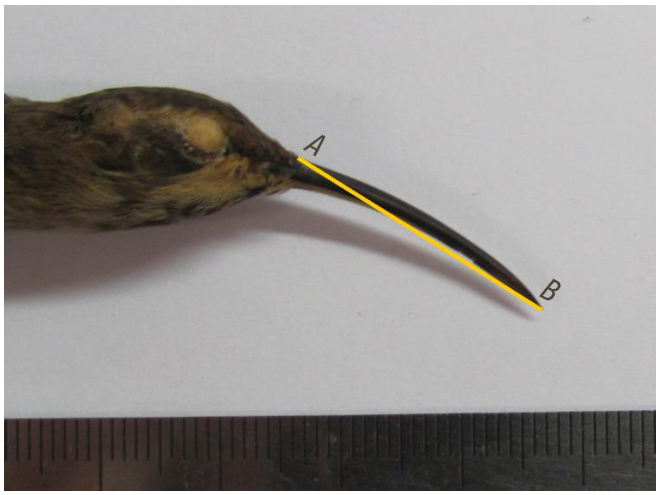

Fig. S1 – Bill length measurement of *Phaethornis rupurumii* (AMNH – 479070) described by the chord of the exposed culmen. A – anterior extension of feathers, B – bill tip.

Bill curvature described the angle of deflection of the exposed culmen, measured by trigonometry rules. First, we placed a scaled grid above the photograph, ensuring that the straight part of the bill was parallel to the horizontal lines of the grid. Then, we measured bill length and deflection length, using the scaled grid. Bill length was measured as a line from the bill tip to the anterior extension of feathers, following the horizontal line from the grid, while deflection length was measured as a line from the bill tip to the bill length's line, creating a 90º angle and, thereby, a right-angle triangle (Fig. S2). Finally, to detect the angle of deflection, we used the tangent rule:

$$tan\,\Theta = \frac{deflection\ length}{bill\ length}$$

converting radians to degree.

Bill length and curvature were log_{10} transformed to achieve normality.

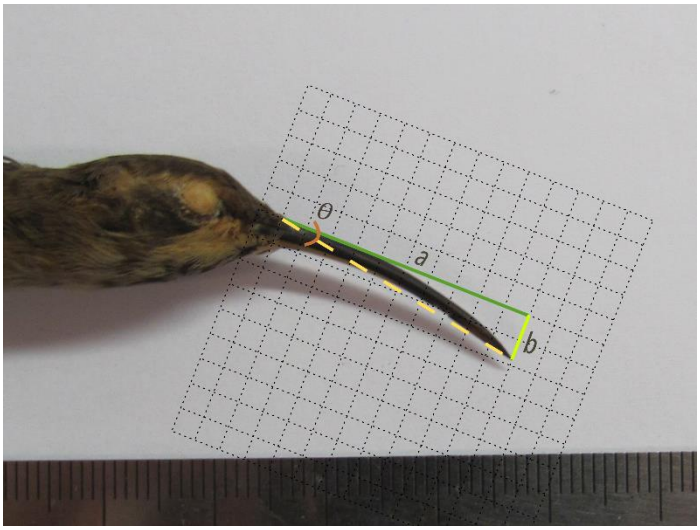

Fig. S2 – Bill curvature measurement of *Phaethornis rupurumii* (AMNH – 479070) described by the angle of deflection. This angle is detected by trigonometry rules using the following parameters: a – bill length's line, b – deflection length's line, *Θ*: angle of deflection.

Table S2 – Museum specimens inspected to measure the morphological traits of hummingbird species.

Species	Museum code
Abeillia abeillei	AMNH-46874, USNM-50316, USNM-50312, USNM-154794, USNM-154796, USNM-149424, USNM-50306, USNM-16597, AMNH-394237, USNM-50403
Adelomyia melanogenys	ZFMK-9031, ZFMK-B1142fB, ZFMK-B1145af, AMNH-145069, AMNH-234438, ZFMK-9022, ZFMK-9026, ZFMK-9021, ZFMK-9023, ZFMK-9027
Aglaeactis aliciae	SMF-80645, AMNH-483090, SMF-80650, SMF-8065, SMF-80651, AMNH-483091, SMF-80654, SMF-80660, SMF-80644, SMF-80655
Aglaeactis castelnaudii	ZMSNM-103084, ZMSNM-103991, ZMSNM-103995, ZMSNM-103085, ZMSNM-103996, ZMSNM-103993, ZMSNM-103997, ZMSNM-103086, ZMSNM-103992, ZMSNM-103994
Aglaeactis cupripennis	ZMSNM-62997, ZMSNM-63004, ZMSNM-63010, ZMSNM-63008, ZMSNM-62995, ZMSNM-63007, ZMSNM-63003, ZMSNM-63012, ZMSNM-63006, ZMSNM-63014
Aglaeactis pamela	SMF-80682, SMF-80673, SMF-80672, SMF-80669, SMF-80670, SMF-80680, SMF-80661, SMF-80679, SMF-80678, SMF-80674
Aglaiocercus berlepschi	FMNH-91918, FMNH-91926, FMNH-91912, FMNH-91911, FMNH-91921, FMNH-91925, FMNH-91915, FMNH-91920, AMNH-70375, FMNH-91923
Aglaiocercus coelestis	ZMSNM-63794, ZMSNM-63793, ZMSNM-63789, ZMSNM-63790, ZMSNM-63796, ZMSNM-63785, ZMSNM-63782, ZMSNM-63781, ZMSNM-63777, ZMSNM-63780
Aglaiocercus kingii	NHMT-1925.12.24.217, NHMT-1969.37.117, NHMT-1969.51.2, NHMT-NL (100), NHMT-NL (99), NHMT-1897.11.12.60, NHMT-1925.12.24.211, NHMT-1925.12.24.213, NHMT-1938.12.20.199, NHMT-1969.38.43
Amazilia amabilis	USNM-469864, USNM-469860, USNM-468793, USNM-461890, USNM-469862, USNM-469863, USNM-207748, USNM-474317, USNM-386037, USNM-484349
Amazilia amazilia	AMNH-129419, AMNH-166839, AMNH-171025, AMNH-171031, AMNH-171033, NHMT-1902.3.13.1938, NHMT-1902.3.13.1939, NHMT-1902.3.13.1940, NHMT-1902.3.13.1942, NHMT-1902.3.13.1943, NHMT-1953.68.137
Amazilia beryllina	AMNH-105384, AMNH-480281, AMNH-480279, AMNH-105383, AMNH-91393, AMNH-105394, AMNH-105397, AMNH-105395, AMNH-105386, AMNH-105385
Amazilia brevirostris	MBML-1629, MBML-1628, MNRJ-33716, MBML-864, MBML-1627
Amazilia boucardi	NHMT-1949.58.1080, NHMT-1949.58.1083, USNM-198672, NHMT-1949.58.1082, NHMT-1925.2.18.1, NHMT-

	1949.58.1081, NHMT-NL (58), NHMT-1908.6.1.1, USNM-198675, NHMT-1949.58.1084, USNM-198668
Amazilia candida	USNM-120233, USNM-356840, USNM-155367, USNM-177332, USNM-371660, USNM-59661, USNM-155365, USNM-166074, USNM-155364, USNM-167488
Amazilia castaneiventris	NHMT-NL (57), USNM-392313, MNRJ-42245, NHMT-88.7.25.137, NHMT-1889.3.22.1826, AMNH-480345
Amazilia chionogaster	NHMT-1946.49.381, NHMT-1946.49.378, NHMT-1946.49.375, NHMT-1946.49.379, AMNH-145021, NHMT-1946.49.382, AMNH-479610, NHMT-1946.49.383, AMNH-168957, AMNH-235435
Amazilia chionopectus	MBML-1629, MBML-864, MBML-1628, MBML-1627, MNRJ 33716
Amazilia cyanifrons	AMNH-480044, AMNH-38693, AMNH-126444, AMNH-38692, USNM-310032, USNM-446253, USNM-22236, USNM-595581, USNM-446256, USNM-446251
Amazilia cyanocephala	AMNH-394079, AMNH-394049, AMNH-394046, AMNH-394060, AMNH-153234, AMNH-394050, AMNH-394052, AMNH-394048, AMNH-394051, AMNH-394047
Amazilia cyanura	AMNH-103694, AMNH-102730, AMNH-480267, AMNH-101176, AMNH-143851, AMNH-103695, AMNH-101170, AMNH-101171, AMNH-103106, AMNH-143852
Amazilia decora	USNM-201185, USNM-201193, USNM-201184, USNM-201188, USNM-201192, USNM-201179, NHMT-NL (71), USNM-192849, NHMT-1882.3.22.1970, NHMT-1949.52.1085
Amazilia edward	NHMT-NL (59), NHMT-1887.514.429, NHMT-1887.3.14.430, NHMT-1887.3.14.431, NHMT-1913.3.20.939, NHMT-1913.3.20.938, NHMT-1913.3.20.937, NHMT-1865.5.19.75, NHMT-1887.3.22.1871, NHMT-1887.3.22.1870
Amazilia fimbriata	AMNH-815899, AMNH-127393, AMNH-479873, MPEG-20928, MPEG-19684, MPEG-20935, MPEG-20941, MPEG-20942, MPEG-20939, MPEG-20943
Amazilia franciae	MBML-1638, MBML-1642, NHMT-1925.12.24.19, NHMT-NL (60), USNM-174082, MBML-1637, MBML-1639, MBML-1640, MBML-1641, NHMT-1925.12.24.18
Amazilia lactea	MPEG-27917, MPEG-27549, MPEG-27551, MPEG-27911, MPEG-27914, MPEG-27912, MPEG-27918, MPEG-27916, MPEG-26382, MPEG-27610
Amazilia leucogaster	MNRJ-18209, MBML-7155, MBML-7301, MNRJ-34329, MNRJ-38135, MNRJ-38136, MBML-7154, MBML-7153, MNRJ-10003, MNRJ-18119
Amazilia luciae	AMNH-781699
Amazilia rosenbergi	MNRJ-40723, MNRJ-40717, MNRJ-40721, MNRJ-40722, MNRJ-48184, MNRJ-40720, MNRJ-48185, MNRJ-41960, MNRJ-40634, MNRJ-40718

Amazilia rutila	AMNH-394040, AMNH-394043, AMNH-394032, AMNH-394035, AMNH-394027, AMNH-394026, AMNH-394039, AMNH-394041, AMNH-394042, AMNH-394028
Amazilia saucerrottei	ZMSNM-62778, ZMSNM-62776, ZMSNM-62774, ZMSNM-62771, ZMSNM-62775, ZMSNM-62769, ZMSNM-62779, ZMSNM-62780, ZMSNM-62773, ZMSNM-62777
Amazilia tobaci	USNM-151674, USNM-151675, USNM-151676, USNM-310019, USNM-310015, USNM-151677, USNM-595586, USNM-175246, USNM-310017, USNM-310018
Amazilia tzacatl	ZMSNM-64061, ZMSNM-62802, FMNH-249596, FMNH-49185, FMNH-11635, MNRJ-41947, MNRJ-42241, MNRJ-42243, MNRJ-40724, MNRJ-42244
Amazilia versicolor	MPEG-27616, MPEG-27940, MPEG-27607, MPEG-27560, MPEG-27567, AMNH-319374, AMNH-34138, MPEG-27617, MPEG-27580, MPEG-27566
Amazilia violiceps	NHMT-NL(65), NHMT-NL(62), NHMT-NL(67), NHMT-NL(64), NHMT-NL(70), NHMT-NL(68), NHMT-NL(61), NHMT-NL(66), NHMT-NL(69), NHMT-NL(63)
Amazilia viridicauda	NHMT-NL (117), AMNH-145024, USNM-273116, AMNH-786653, USNM-273117, USNM-273114, AMNH-145022, AMNH-786654, USNM-273125, NHMT-NL (118), USNM-273115
Amazilia viridifrons	FMNH-208727, FMNH-208726, FMNH-470525, FMNH-470526, AMNH-815304, AMNH-815303, FMNH-208728, FMNH-153210, FMNH-470527, FMNH-470528
Amazilia virigaster	NHMT-2002-3-501, NHMT-2002-3-502, NHMT-2002-3-499, NHMT-2002-3-505, NHMT-2002-3-508, NHMT-2002-3-509, NHMT-2002-3-513, NHMT-2002-3-504, NHMT-2002-3-495, NHMT-2002-3-506
Amazilia wagneri	AMNH-815301, AMNH-815302
Amazilia yucatanensis	USNM-134932, USNM-134931, USNM-142259, USNM-176195, USNM-158759, USNM-176194, USNM-134933, USNM-134936, USNM-134930, USNM-134939
Androdon aequatorialis	AMNH-111529, AMNH-154731, AMNH-478679, AMNH-478676, AMNH-478677, AMNH-478678, AMNH-111531, AMNH-111532, AMNH-478680, AMNH-117641, AMNH-123262
Anopetia gounellei	MNRJ-32153, MPEG-MG 67.907, MPEG-75492, MPEG-76741, MPEG-76740, MPEG-75488, MNRJ-32119, MNRJ-17965, MNRJ-43404, MPEG-76790
Anthocephala floriceps	NHMT-2002.3.634, AMNH-111563, AMNH-482143, AMNH-11564, USNM-135130, USNM-135131, AMNH-76492, AMNH-76493, AMNH-76491, AMNH-73059
Anthracothorax dominicus	AMNH-482128, AMNH-101947, AMNH-482115, AMNH-269853, AMNH-101946, AMNH-482132, AMNH-482118, AMNH-101945, AMNH-482113, AMNH-482130

Anthracothorax mango	NHMT-1887.3.22.398, NHMT-1915.5.1.1204, NHMT-NL (73), NHMT-1915.5.1.1202, NHMT-1919.9.10.98, NHMT-1913.3.20.117, NHMT-1887.3.14.95, NHMT-1887.3.14.97, NHMT-NL (72), NHMT-NL (74)
Anthracothorax nigricollis	MNRJ-41459, MNRJ-41460, MNRJ-41454, MNRJ-41458, MNRJ-41456, MNRJ-41451, MNRJ-41450, MNRJ-41462, MNRJ-41463, MNRJ-41461
Anthracothorax prevostii	NHMT-1912.1.1.46, NHMT-1912.1.1.48, NHMT-1912.1.1.53, NHMT-1912.7.1.43, NHMT-1912.1.1.50, NHMT-1912.1.1.51, NHMT-1912.7.1.40, NHMT-1912.7.1.41, NHMT-1912.7.1.44, NHMT-1912.7.1.45
Antracothorax veraguensis	NHMT-1913.3.20.288, NHMT-1853.11.28.18, USNM-400286, NHMT-1913.3.20.290, NHMT-1913.3.20.291, NHMT-1913.3.20.289, NHMT-1887.3.22.415, NHMT-1887.3.22.416, NHMT-1887.3.22.417, NHMT-NL (75)
Anthracothorax viridigula	MPEG-15545, MPEG-56582, MPEG-47364, MNRJ-18036, MPEG-56583, MPEG-53316, MPEG-53313, MPEG-58040, MPEG-53314, MPEG-53315
Anthracothorax viridis	USNM-171616, USNM-238805, USNM-354733, USNM-171498, USNM-238806, USNM-171623, USNM-231794, USNM-238807, USNM-231791, USNM-171497
Aphantochroa cirrochloris	MNRJ-48231, MNRJ-41401, MNRJ-41398, MNRJ-41407, MNRJ-41399, AMNH-314059, MNRJ-41402, MNRJ-41405, MNRJ-41404, MNRJ-41398
Archilochus alexandri	AMNH-754528, AMNH-754529, AMNH-754504, AMNH-764484, AMNH-754505, AMNH-29348, AMNH-754513, AMNH-29362, AMNH-29357, AMNH-29346
Archilochus colubris	AMNH-789495, AMNH-484649, AMNH-824191, AMNH-484660, AMNH-361444, AMNH-484643, AMNH-484642, AMNH-484641, AMNH-484645, AMNH-484644
Atthis ellioti	NHMT-1913.3.20.574, NHMT-1913.3.20.583, NHMT-1913.3.20.573, NHMT-1913.3.20.577, NHMT-1913.3.20.575, NHMT-1887.3.22.1106, NHMT-NL (139), NHMT-NL (137), NHMT-NL (138), NHMT-1887.3.22.1112
Atthis heloisa	AMNH-754700, AMNH-754698, AMNH-754694, AMNH-754691, AMNH-648897, AMNH-754693, AMNH-754688, AMNH-484963, AMNH-754689, AMNH-648898
Augastes lumachella	MBML-989, MBML-981, MBML-996, MBML-999, MBML-964, MBML-1009, MBML-1007, MBML-1483, MBML-1006, MBML-1011
Augastes scutatus	MNRJ-40135, MNRJ-40155, MNRJ-40141, MNRJ-40121, MNRJ-40153, MNRJ-40187, MNRJ-40186, MNRJ-40185, MNRJ-40189, MNRJ-40190
Avocettula recurvirostris	NHMT-1922.3.5.1076, NHMT-1885.3.22.1431, FMNH-63234, NHMT-1888.7.25.235, AMNH-38214, FMNH-45496, NHMT-1922.3.5.4684, NHMT-1922.3.5.4683, AMNH-481921, NHMT-1887.7.25.236, NHMT-1913.3.20.976

Basilinna leucotis	ZFMK-80584, ZFMK-7458, ZFMK-7455, AMNH-815293, ZFMK-7456, AMNH-815294, ZFMK-80585, ZFMK-7468, ZFMK-7465, ZFMK-7462, AMNH-813334, ZFMK-80583, ZFMK-7454
Basilinna xantusii	AMNH-754802, FMNH-161010, FMNH-159994, FMNH-160999, FMNH-161000, FMNH-161001, AMNH-754789, AMNH-81723, AMNH-754801, FMNH-138655
Boissonneaua flavescens	ZFMK-8849, ZFMK-8850, ZFMK-8851, ZFMK-81385, ZFMK-B1141ca, ZFMK-8852, ZFMK-8848, ZFMK-8843, ZFMK-8847, ZFMK-8844
Boissonneaua jardini	MNRJ-40483, MNRJ-40480, MNRJ-40479, MNRJ-40484, NHMT-1969.37.88, MNRJ-40486, NHMT-1940.12.5.524, NHMT-1953.68.216, NHMT-1969.37.87, NHMT-1925.12.24.92
Boissonneaua matthewsii	ZFMK-84118, ZFMK-8837, AMNH-235819, ZFMK-8839, ZFMK-8841, ZFMK-8842, ZFMK-84119, AMNH-234428, ZFMK-8834, ZFMK-8832
Calliphlox amethystina	MNRJ-39932, MNRJ-39831, MNRJ-39830, MNRJ-39838, MNRJ-39829, MNRJ-39828, MNRJ-48186, MNRJ-39809, MNRJ-39837, MNRJ-39811
Calliphlox bryantae	NHMT-1969.25.723, NHMT-1992.3.21, NHMT-72.5.28.43, NHMT-1969-25-721, NHMT-1912.7.1.209, NHMT-1969-25-717, NHMT-1887.3.22.1208, NHMT-1969.25.714, NHMT-1887.3.22.1205, NHMT-1992.3.20
Calliphlox evelynae	USNM-74666, AMNH-37970, USNM-74668, ZFMK-87058, USNM-74660, ZFMK-9768, ZFMK-9773, USNM-352824, ZFMK-9766, ZFMK-9770
Calliphlox mitchellii	AMNH-117706, AMNH-484599, AMNH-824739, AMNH-117704, AMNH-109538, AMNH-124281, USNM-174568, USNM-595600, USNM-128502, USNM-174569
Calothorax lucifer	ZFMK-9699, ZFMK-9701, ZFMK-9695, ZFMK-9700, ZFMK-9694, ZFMK-9697, ZFMK-9688, ZFMK-9698, AMNH-754444, AMNH-484527
Calothorax pulcher	NHMT-NL (78), NHMT-NL (76), NHMT-1887.3.22.1197, NHMT-1887.3.22.1123, NHMT-1887.3.22.124, NHMT-1993.3.20.572, NHMT-NL (80), NHMT-NL (81), NHMT-NL (79), NHMT-NL (77), USNM-154789
Calypte anna	AMNH-361595, AMNH-361635, AMNH-361630, AMNH-754542, AMNH-49374, AMNH-754540, AMNH-754563, AMNH-98808, AMNH-351568, AMNH-821343
Calypte costae	USNM-117267, USNM-99368, USNM-262690, USNM-134370, USNM-462941, USNM-99216, USNM-529133, USNM-299666, USNM-239853, USNM-240872
Campylopterus curvipennis	NHMT-NL(85), NHMT-1887.3.22.208, NHMT-NL(83), NHMT-NL(82), NHMT-1887.3.14.36, NHMT-1887.3.22.209, NHMT-NL(84), NHMT-NL(87), NHMT-NL(86), NHMT-1955.6.N.16.106

Campylopterus duidae	AMNH-270813, AMNH-270734, AMNH-270792, AMNH-270828, AMNH-270752, AMNH-270745, AMNH-270815, AMNH-270774, AMNH-270785, AMNH-270817
Campylopterus ensipennis	AMNH-120419, AMNH-120413, AMNH-188188, AMNH-120412, SMF-81854, SMF-81858, SMF-81855, SMF-81856, AMNH-129093, SMF-81852
Campylopterus excellens	USNM-359710, USNM-359708, USNM-359709, FMNH-136132, USNM-359711, FMNH-343205
Campylopterus falcatus	AMNH-322925, AMNH-179997, AMNH-479384, AMNH-100462, AMNH-179995, AMNH-479369, AMNH-479370, AMNH-406484, AMNH-428783, AMNH-131178
Campylopterus hemileucurus	ZFMK-6911, ZFMK-6912, ZFMK-6916, ZFMK-6910, ZFMK-6913, ZFMK-6906, ZFMK-6892, ZFMK-6909, ZFMK-6908, ZFMK-6899
Campylopterus hyperythrus	AMNH-236563, AMNH-236564, NHMT-1911.11.14.57, AMNH-156264, NHMT-1887.3.22.234, NHMT-1911.11.14.122, NHMT-1911.11.14.56, NHMT-1887.3.22.233, NHMT-1922.3.5.1063, NHMT-1922.3.5.1065
Campylopterus largipennis	AMNH-479310, AMNH-479311, MPEG-33543, MPEG-51330, MPEG-51331, MPEG-67275, AMNH-479307, MPEG-31003, MPEG-67274, MPEG-67276
Campylopterus pampa	USNM-50266, USNM-50270, FMNH-45735, USNM-302575, USNM-50264, FMNH-42482
Campylopterus phainopeplus	USNM-386939, NHMT-1887.3.22.296, NHMT-1887.3.22.268, USNM-386941, NHMT-2002.3.129, NHMT-2002.3.128, USNM-386940, NHMT-1887.3.22.270, NHMT-1887.3.22.267, NHMT-1887.3.22.263
Campylopterus rufus	AMNH-46283, AMNH-393949, AMNH-393951, AMNH-393952, AMNH-479399, AMNH-813326, AMNH-813327, AMNH-813328, AMNH-813329, AMNH-813330
Campylopterus villaciscensio	MNRJ-40704, NHMT-1887.3.22.260, NHMT-1887.3.22.262, NHMT-1902.3.13.1904, NHMT-1940.12.5.572, NHMT-1953.68.256, NHMT-1953.68.256B, NHMT-NL (124), NHMT-NL (125), NHMT-NL (126)
Chaetocercus astreans	AMNH-3093, AMNH-3094, AMNH-305591, AMNH-305592
Chaetocercus berlepschi	AMNH-118532, AMNH-118533, AMNH-118529, AMNH-118530, AMNH-118531, AMNH-118534, AMNH-119766, AMNH-119768, MBML-1521, MBML-1526
Chaetocercus bombus	AMNH-37934, AMNH-37935, AMNH-171159, AMNH-179065, AMNH-235859, AMNH-235860, AMNH-484949, AMNH-484950, AMNH-484951, AMNH-484956
Chaetocercus heliodor	AMNH-100680, AMNH-100685, AMNH-484851, AMNH-484858, AMNH-484861, AMNH-484867, AMNH-484870, AMNH-484882, AMNH-484883, AMNH-484884

Chaetocercus jourdanii	ZFMK-9955, ZFMK-9956, ZFMK-9958, ZFMK-9959, ZFMK-9960, ZFMK-9964, ZFMK-9965, ZFMK-9966, ZFMK-9969, ZFMK-9971
Chaetocercus mulsant	ZFMK-81346, ZFMK-9914, ZFMK-9911, ZFMK-9913, MBML-1529, ZFMK-9909, ZFMK-9917, ZFMK-9904, MBML-1527, MBML-1528
Chalcostigma herrani	ZMSNM-63756, ZMSNM-63757, ZMSNM-63759, ZMSNM-63755, ZMSNM-63758, ZMSNM-63751, ZMSNM-63742, ZMSNM-63745, ZMSNM-63748, ZMSNM-63744
Chalcostigma heteropogon	AMNH-38186, AMNH-38188, AMNH-46799, AMNH-46800, AMNH-483915, AMNH-483920, AMNH-483925, AMNH-483926, AMNH-483927, AMNH-483930
Chalcostigma olivaceum	AMNH-38181, AMNH-174050, AMNH-174052, AMNH-229187, AMNH-874051, NHMT-1887.3.14.256, NHMT-1887.3.14.258, NHMT-1902.3.13.2096, NHMT-1902.3.13.2098, USNM-273100
Chalcostigma ruficeps	NHMT-1887.3.22.1414, NHMT-1902.3.13.2100, NHMT-1902.3.13.2102, NHMT-1913.3.20.211, NHMT-NL (127), NHMT-NL (128), NHMT-NL (129), NHMT-NL (130), NHMT-NL (131), NHMT-NL (132)
Chalcostigma stanleyi	AMNH-483936, NHMT-1887.3.22.1399, NHMT-1887.3.44.254, NHMT-1888.7.25.239, NHMT-1897.11.12.77, NHMT-1897.11.12.78, NHMT-1902.3.13.2092, NHMT-1916.8.24.44, NHMT-1916.8.24.45, NHMT-1938.12.20.235
Chalybura buffonii	MBML-1099, MBML-1101, ZFMK-7934, ZFMK-7936, ZFMK-7938, ZFMK-7941, ZFMK-9420, ZFMK-9432, ZFMK-10244, ZFMK-53361
Chalybura urochrysia	USNM-433595, USNM-433596, USNM-445007, USNM-469753, USNM-476666, USNM-477675, USNM-477677, USNM-477679, USNM-484318, USNM-484319
Chlorestes notata	MPEG-5317, MPEG-31831, MPEG-15527, MPEG-15534, MPEG-29720, MPEG-26929, MPEG-30539, MPEG-17818, MPEG-28490, MPEG-72417
Chlorostilbon alice	AMNH-150241, FMNH-35228, FMNH-45988, FMNH-91934, FMNH-91936, FMNH-91938, NHMT-1887.3.14.482, NHMT-1913.3.20.962, NHMT-1913.3.20.964, NHMT-1947.7.16.17
Chlorostilbon assimilis	USNM-150784, USNM-316677, USNM-376203, USNM-376211, USNM-400321, USNM-400330, USNM-409383, USNM-409384, USNM-409386, USNM-409387
Chlorostilbon auriceps	AMNH-38786, AMNH-182346, AMNH-481017, AMNH-481018, AMNH-481019, AMNH-481022, AMNH-481023, AMNH-815290, USNM-126618, USNM-157166, USNM-186035
Chlorostilbon bracei	FMNH-42413, FMNH-42414, FMNH-42421, FMNH-42423, FMNH-42424, FMNH-42429, FMNH-42431, FMNH-42435, FMNH-42440, FMNH-42445, FMNH-42447, FMNH-42448

Chlorostilbon canivetii	AMNH-47082, AMNH-10438, AMNH-12038, AMNH-12534, AMNH-38792, AMNH-706254, AMNH-47097, AMNH-47096, AMNH-38794, AMNH-38790
Chlorostilbon forficatus	USNM-102813, USNM-102814, USNM-102816, USNM-102817, USNM-102820, USNM-102821, USNM-102822, USNM-167483, USNM-167484, USNM-167485
Chlorostilbon gibsoni	USNM-410803, USNM-392295, USNM-392294, USNM-401512, USNM-392297, USNM-392156, USNM-410781, USNM-372771, USNM-401511, USNM-372769
Chlorostilbon lucidus	MNRJ-41317, MNRJ-41310, MNRJ-41227, MNRJ-41309, MNRJ-41283, MNRJ-41230, MNRJ-41218, MNRJ-41301, MNRJ-41216, MNRJ-41220
Chlorostilbon maugaeus	USNM-238824, USNM-171607, USNM-171500, USNM-171613, USNM-169116, USNM-238822, USNM-171611, USNM-171610, USNM-231760, USNM-238830
Chlorostilbon melanorhynchus	USNM-173546, USNM-446332, ZFMK-9279, ZFMK-9280, ZFMK-9281, ZFMK-9282, ZFMK-9295, ZFMK-9298, ZFMK-9299, ZFMK-9306
Chlorostilbon mellisugus	USNM-151692, USNM-309884, USNM-329516, USNM-351903, USNM-533671, USNM-329515, USNM-351901, USNM-309883, USNM-329513, USNM-329514
Chlorostilbon olivaresi	No specimens; Rosero-Laspilla, L. unpublished data
Chlorostilbon poortmani	AMNH-481204, AMNH-481206, AMNH-481205, AMNH-54292, AMNH-154447, AMNH-481189, AMNH-47121, AMNH-54311, AMNH-437536, AMNH-54325
Chlorostilbon ricordii	ZFMK-7751, ZFMK-7752, ZFMK-7750, ZFMK-7746, ZFMK-7753, ZFMK-7748, ZFMK-7747, ZFMK-7742, ZFMK-7744, ZFMK-7749
Chlorostilbon russatus	USNM-170606, USNM-368847, USNM-372757, USNM-372760, USNM-372761, USNM-383601, USNM-383603, USNM-383605, USNM-383609, USNM-383610
Chlorostilbon stenurus	USNM-173576, USNM-190513, ZFMK-7723, ZFMK-7725, ZFMK-7726, ZFMK-7728, ZFMK-7729, ZFMK-7731, ZFMK-7733, ZFMK-7734
Chlorostilbon swainsonii	FMNH-1271, FMNH-1298, FMNH-42453, FMNH-42454, FMNH-42455, FMNH-42456, FMNH-42460, FMNH-42464, FMNH-67350, FMNH-67351
Chrysolampis mosquitus	MNRJ-41104, MNRJ-41061, MNRJ-41101, MNRJ-41107, MNRJ-41063, MNRJ-41049, MNRJ-41046, MNRJ-41096, MNRJ-41110, MNRJ-41095
Chrysuronia oenone	ZFMK-587, ZFMK-81375, ZFMK-84146, ZFMK-571717, ZFMK-1982/43, ZFMK-7537, ZFMK-7539, ZFMK-7540, ZFMK-571715, ZFMK-571718
Clytolaema rubricauda	MNRJ-42319, MNRJ-42340, MNRJ-42317, MNRJ-42320, MNRJ-42302, MNRJ-42283, MNRJ-42286, MNRJ-42306, MNRJ-42309, MNRJ-42308

Coeligena bonapartei	USNM-48140, USNM-79279, USNM-108995, USNM-127640, USNM-127641, USNM-149150, USNM-149151, USNM-149152, USNM-309590, USNM-309591
Coeligena coeligena	ZFMK-8899, ZFMK-8911, ZFMK-8901, ZFMK-8915, AMNH-111593, ZFMK-8904, ZFMK-8905, AMNH-111601, AMNH-111600, AMNH-107845
Coeligena helianthea	ZFMK-8540, ZFMK-8539, ZFMK-10296, ZFMK-8537, MBML-1250, ZFMK-10293, ZFMK-8530, ZFMK-8531, ZFMK-8532, ZFMK-10294
Coeligena iris	FMNH-57568, NHMT-1887.3.22.720, NHMT-1887.3.22.719, NHMT-1969.37.85, NHMT-1887.3.14.334, NHMT-1888.7.25.251, NHMT-1969.37.86, NHMT-1888.7.25.249, NHMT-1887.3.14.333, NHMT-1953.68.227
Coeligena lutetiae	ZFMK-8583, ZFMK-8589, ZFMK-8581, ZFMK-8582, ZFMK-8584, ZFMK-8578, ZFMK-8588, ZFMK-8576, ZFMK-8590, ZFMK-8579
Coeligena orina	USNM-436219
Coeligena phalerata	USNM-386942, USNM-386943, USNM-386947, USNM-386948, USNM-386949, USNM-386951, USNM-386953, USNM-386955, USNM-386956, USNM-386957
Coeligena prunellei	NHMT-1913.3.20.207, NHMT-1887.3.14.345, NHMT-2002.3.942, NHMT-2002.3.941, NHMT-2002.3.945, NHMT-2002.3.946, NHMT-2002.3.948, NHMT-1887.3.22.768, NHMT-2002.3.944, NHMT-1913.3.20.209
Coeligena torquata	ZFMK-8615, ZFMK-8621, ZFMK-8618, ZFMK-84256, ZFMK-8612, ZFMK-84120, ZFMK-8620, ZFMK-8617, ZFMK-8619, ZFMK-8605
Coeligena violifer	AMNH-34542, AMNH-169581, AMNH-169583, AMNH-169584, AMNH-169585, AMNH-235447, AMNH-235448, AMNH-235449, AMNH-235450, AMNH-482803, AMNH-482804
Coeligena wilsoni	AMNH-124151, USNM-173754, USNM-173753, USNM-173758, AMNH-124155, AMNH-154774, AMNH-166889, USNM-173955, USNM-173756, USNM-173752
Colibri coruscans	MNRJ-42157, MNRJ-42170, MNRJ-42159, MNRJ-42172, MNRJ-42156, ZFMK-54724, ZFMK-8043, ZFMK-8040, ZFMK-8020, ZFMK-8034
Colibri delphinae	ZFMK-7957, ZFMK-7959, ZFMK-7965, MBML-91, MBML-89, MBML-90, MBML-88, MBML-92, MBML-100, MBML-96
Colibri serrirostris	MNRJ-41333, MNRJ-41334, MNRJ-41341, MNRJ-41360, MNRJ-41377, MNRJ-41385, MNRJ-41348, MNRJ-41366, MNRJ-41347, MNRJ-42174
Colibri thalassinus	ZFMK-8001, ZFMK-8014, AMNH-811722, AMNH-246080, AMNH-99551, ZFMK-8012, ZFMK-8009, ZFMK-8002, ZFMK-8010, ZFMK-8007

Cyanophaia bicolor	SMF-84478, SMF-84481, SMF-84479, SMF-84480, AMNH-481323, SMF-84472, SMF-84476, SMF-84473, SMF-84474, SMF-84469
Cynanthus doubledayi	USNM-155332, USNM-155333, USNM-155335, USNM-155336, USNM-155337, USNM-155340, USNM-155341, USNM-186058, USNM-186059, USNM-186062
Cynanthus latirostris	AMNH-480436, AMNH-480438, AMNH-706248, AMNH-480449, AMNH-480435, AMNH-754828, AMNH-821473, AMNH-480441, AMNH-105406, AMNH-91420
Cynanthus sordidus	NHMT-1858.10.1.1, NHMT-1858.10.1.2, NHMT-1869.6.4.93, NHMT-1887.3.22.2139, NHMT-1887.3.22.2140, NHMT-1888.7.25.258, NHMT-1888.7.25.259, NHMT-1888.7.25.261, NHMT-NL (88), NHMT-NL (89)
Damophila julie	USNM-392226, USNM-392227, USNM-392228, USNM-401584, ZFMK-7574, ZFMK-7575, ZFMK-9218, ZFMK-10230, ZFMK-10232, ZFMK-10238
Discosura conversii	SMF-84049, SMF-84050, SMF-84051, SMF-84053, SMF-84054, SMF-84055, SMF-84060, SMF-84069, SMF-84070, SMF-84071
Discosura langsdorffi	NHMT-1913.3.20.541, NHMT-1913.3.20.540, NHMT-1895.4.1.1005, NHMT-1913.3.20.544, NHMT-NL (112), NHMT-NL (110), NHMT-NL (113), NHMT-NL (111), NHMT-1887.3.22.1301, NHMT-NL (109)
Discosura longicaudis	MNRJ-41961, NHMT-1887.3.10.1211, NHMT-1922.3.5.1171, NHMT-NL (135), NHMT-NL (134), NHMT-1887.3.22.1310, NHMT-NL (136), NHMT-1922.3.5.1172, NHMT-1887.3.22.1312, NHMT-1922.3.5.1167
Discosura popelairii	NHMT-1913.3.20.560, NHMT-1940.12.5.586, NHMT-1940.12.5.588, NHMT-1940.12.5.590, NHMT-1940.12.5.591, NHMT-1940.12.5.593, NHMT-1940.12.5.596, NHMT-1953.68.197, NHMT-1969.37.50, NHMT-1969.37.51
Discosura letitiae	NHMT-1888.7.25.83
Doricha eliza	AMNH-37957, NHMT-1887.3.14.213, NHMT-1887.3.22.1199, NHMT-1887.3.22.1200, NHMT-1887.3.22.1201, NHMT-1913.3.20.632, NHMT-1913.3.20.634, NHMT-NL (106), NHMT-NL (107), NHMT-NL (108)
Doricha enicura	AMNH-37946, AMNH-37947, AMNH-46635, AMNH-46637, AMNH-394200, AMNH-394208, AMNH-484620, AMNH-484621, AMNH-484622, AMNH-484625
Doryfera johannae	AMNH-185192, AMNH-460149, AMNH-185191, AMNH-185195, AMNH-179027, AMNH-185193, AMNH-179024, AMNH-179026, AMNH-825615, AMNH-37595
Doryfera ludoviciae	ZFMK-10160, AMNH-179978, ZFMK-6662, ZFMK-6663, ZFMK-84149, ZFMK-10158, ZFMK-6659, ZFMK-6664, ZFMK-87078, MBML-1702

Elvira chionura	USNM-458551, USNM-533413, ZFMK-7919, ZFMK-7920, ZFMK-7921, ZFMK-7923, ZFMK-7924, ZFMK-7925, ZFMK-7927, ZFMK-7929
Elvira cupreiceps	AMNH-38569, AMNH-38590, AMNH-99547, AMNH-389643, AMNH-389645, AMNH-389646, AMNH-389647, AMNH-481677, AMNH-481680, AMNH-481682
Ensifera ensifera	ZMSNM-63162, ZMSNM-63160, ZMSNM-63163, ZMSNM-63159, ZMSNM-63165, ZMSNM-63150, ZMSNM-63151, ZMSNM-63145, ZMSNM-63157, ZMSNM-63155
Eriocnemis aline	SMF-88301, SMF-88304, SMF-88305, SMF-88306, SMF-88307, SMF-88309, SMF-88310, SMF-88315, ZFMK-10312, ZFMK-10314, ZFMK-B1142
Eriocnemis cupreoventris	ZFMK-8914, ZFMK-8909, ZFMK-8915, ZFMK-9627, ZFMK-9623, ZFMK-8907, ZFMK-8906, ZFMK-8910, ZFMK-8908, ZFMK-8913
Eriocnemis derbyi	ZMSNM-63431, ZMSNM-63430, ZMSNM-63435, ZMSNM-63436, ZMSNM-63433, ZMSNM-63429, ZMSNM-63428, ZMSNM-63421, ZMSNM-103978, ZMSNM-63425
Eriocnemis glaucopoides	AMNH-138682, FMNH-293705, FMNH-293706, FMNH-293710, FMNH-293712, FMNH-293715, FMNH-293717, FMNH-293718, ZFMK-8879, ZFMK-55417
Eriocnemis godini	AMNH-38438, AMNH-483217, AMNH-483218, FMNH-46228, NHMT-1887.3.22.1644, NHMT-1888.7.25.176, NHMT-1988.21.48
Eriocnemis luciani	ZFMK-8871, ZFMK-8873, ZFMK-8872, MNRJ-42118, MNRJ-42118, ZFMK-8868, ZFMK-8870, ZFMK-8876, ZFMK-5918, ZFMK-5910
Eriocnemis mirabilis	AMNH-788368, USNM-533486
Eriocnemis mosquera	NHMT-1887.3.22.1631, NHMT-1887.3.22.1635, NHMT-1887.3.22.1634, NHMT-1897.11.12.93, NHMT-1887.3.22.1630, NHMT-1887.3.22.1632, NHMT-1938.12.20.226, NHMT-1938.12.20.227, NHMT-1938.12.20.195, NHMT-1938.12.20.196
Eriocnemis nigrivestis	ZMSNM-63257, ZMSNM-63258, ZMSNM-63259, ZMSNM-63263, ZMSNM-63265, ZMSNM-63272, ZMSNM-63274, ZMSNM-63275, ZMSNM-63276, ZMSNM-63277
Eriocnemis vestita	ZFMK-8897, ZFMK-8892, ZFMK-8890, ZFMK-8891, ZFMK-9607, ZFMK-8881, ZFMK-8895, ZFMK-8883, ZFMK-8896, ZFMK-8887
Eugenes fulgens	ZFMK-8374, ZFMK-8384, ZFMK-80570, ZFMK-80571, ZFMK-80573, ZFMK-8363, ZFMK-8364, ZFMK-8371, ZFMK-80564, ZFMK-86270
Eulampis holosericeus	AMNH-482181, AMNH-482180, AMNH-482205, SMF-83751, SMF-83752, AMNH-86888, AMNH-482211, AMNH-482204, SMF-83755, SMF-83764

Eulampis jugularis	ZFMK-8206, ZFMK-8208, ZFMK-87035, ZFMK-87036, ZFMK-81676, ZFMK-86275, ZFMK-8202, ZFMK-8200, ZFMK-8198, ZFMK-8201
Eulidia yarellii	AMNH-37984, AMNH-37985, AMNH-37987, NHMT-1869.6.4.69, NHMT-1933.11.14.57, NHMT-NL (30), NHMT-NL (31), NHMT-NL (32), SMF-75844, SMF-75845, SMF-75846, SMF-75847, SMF-75850, USNM-536993
Eupetomena macroura	AMNH-479441, MPEG-22628, AMNH-242010, AMNH-242040, MPEG-32899, MPEG-22633, MPEG-57825, MPEG-57824, MPEG-57823, MPEG-32898
Eupherusa cyanophrys	AMNH-766563, AMNH-799169, AMNH-815306, AMNH-815307, AMNH-815309, AMNH-815310, AMNH-815311, AMNH-832535, FMNH-346837, FMNH-459514
Eupherusa eximia	AMNH-38569, AMNH-46971, AMNH-46973, AMNH-101192, AMNH-103331, AMNH-143881, AMNH-143883, AMNH-394148, AMNH-394150, AMNH-394151, AMNH-481627
Eupherusa nigriventris	NHMT-1887.3.22.1758, NHMT-1887.3.22.1761, NHMT-1913.3.20.813, NHMT-1949.58.1231, NHMT-NL (101), NHMT-1887.3.22.1759, NHMT-1887.3.22.1760, NHMT-1913.3.20.812, NHMT-1913.3.20.814, NHMT-1969.25.686
Eupherusa poliocerca	USNM-186475, AMNH-481644, AMNH-481645, AMNH-481647, AMNH-481648, AMNH-481649, FMNH-343721, FMNH-343722, NHMT-1988.21.41, NHMT-1988.21.42, NHMT-1988.21.43
Eutoxeres aquila	SMF-85496, SMF-85477, SMF-85505, SMF-85483, SMF-85497, SMF-85476, SMF-85487, SMF-85495, SMF-85486, SMF-85508
Eutoxeres condamini	FMNH-286839, FMNH-292769, FMNH-292770, FMNH-293218, NHMT-1887.3.22.13, NHMT-1887.3.22.14, NHMT-1887.3.22.15, NHMT-2000.1.77, NHMT-NL (34), NHMT-NL (35)
Florisuga fusca	MNRJ-40298, MNRJ-40278, MNRJ-40262, MNRJ-40287, MNRJ-40266, MNRJ-40298, MNRJ-40294, MNRJ-40295, MNRJ-40301, MNRJ-40284
Florisuga mellivora	MPEG-50535, MPEG-50534, MPEG-53838, MPEG-56581, MPEG-62279, MPEG-49824, MPEG-49825, MPEG-62472, MPEG-62473, MPEG-74502
Glaucis aeneus	NHMT-1887.3.22.24, NHMT-1912.7.1.252, USNM-126280, USNM-468765, USNM-468766, USNM-605203, USNM-606072, USNM-606751, USNM-606757, USNM-607665
Glaucis dohrnii	MNRJ-18379, MNRJ-39351, MNRJ-39352, MBML-617, MBML-7251, MNRJ-31504, MNRJ-43579, MNRJ-39367, MBML-610, MBML-615
Glaucis hirsutus	MPEG-47362, MPEG-47363, MPEG-50248, MPEG-47361, MPEG-43939, MPEG-47358, MPEG-47354, MPEG-47356, MPEG-47355, MPEG-47357

Goethalsia bella	AMNH-131870, AMNH-824797, USNM-238672, USNM-529701, USNM-529702
Goldmania violiceps	USNM-207756, USNM-207761, USNM-409368, USNM-409369, USNM-409373, USNM-468680, USNM-469724, USNM-484327, USNM-484330, USNM-484332
Haplophaedia assimilis	AMNH-74132, AMNH-146002, AMNH-146003, AMNH-146004, AMNH-146005, AMNH-146006, AMNH-149869, AMNH-483281, AMNH-483282, AMNH-483283
Haplophaedia aureliae	ZFMK-9648, ZFMK-9652, ZFMK-9649, ZFMK-8928, ZFMK-8929, ZFMK-9638, ZFMK-9645, ZFMK-9639, ZFMK-9643, USNM-425756
Haplophaedia lugens	FMNH-249608, FMNH-251050, MBML-1353, NHMT-1913.3.20.477, NHMT-1920.10.31.59, NHMT-1925.12.24.254, USNM-174489, USNM-174490, USNM-174492, USNM-174494
Heliactin bilophus	MNRJ-18728, MNRJ-18575, MNRJ-18556, MNRJ-33108, MNRJ-40208, MNRJ-18729, MNRJ-18723, MNRJ-18793, MNRJ-9792, MNRJ-40206
Heliangelus amethysticollis	USNM-372922, USNM-372915, USNM-372918, USNM-372919, USNM-372929, USNM-372925, USNM-372930, USNM-372917, USNM-372931, USNM-372920
Heliangelus exortis	SMF-89071, SMF-89072, SMF-89083, SMF-89073, ZFMK-B1146dE, SMF-89078, SMF-89079, SMF-89081, SMF-89080, ZFMK-9133
Heliangelus mavors	AMNH-483575, AMNH-483597, AMNH-483598, AMNH-483600, ZFMK-9065, ZFMK-9066, ZFMK-9068, ZFMK-9069, ZFMK-9076, ZFMK-9078
Heliangelus micraster	AMNH-483717, AMNH-483720, FMNH-46288, FMNH-222192, NHMT-1887.3.22.886, NHMT-1887.3.22.887, NHMT-NL (36), NHMT-NL (37), NHMT-NL (38)
Heliangelus regalis	AMNH-823988, AMNH-823989, FMNH-299433, ZMSNM-103068
Heliangelus strophianus	AMNH-46534, SMF-89033, SMF-89034, SMF-89035, SMF-89036, SMF-89037, USNM-173980, USNM-173997, USNM-173998, USNM-174000
Heliangelus viola	AMNH-129496, AMNH-166962, AMNH-129498, AMNH-166981, AMNH-166963, AMNH-166982, AMNH-129494, AMNH-129497, AMNH-166970, AMNH-171119
Heliangelus micraster	NHMT-1888.7.25.174
Heliodoxa aurescens	MPEG-72995, MPEG-62476, MNRJ-38068, MPEG-63434, MPEG-53985, MPEG-69148, MPEG-66009, MPEG-52718, MPEG-41765, MPEG-41617
Heliodoxa branickii	FMNH-310545, FMNH-310546, FMNH-310547, FMNH-310552, FMNH-310553, FMNH-310555, FMNH-315371, FMNH-315380, FMNH-320955, FMNH-320959

Heliodoxa gularis	AMNH-179040, AMNH-179041, AMNH-179042, AMNH-185112, AMNH-185113, NHMT-1888.7.25.156, NHMT-2000.1.84, ZFMK-87218, ZFMK-87219
Heliodoxa imperatrix	NHMT-1897.11.12.67, NHMT-1887.3.22.584, NHMT-1913.3.20.52, NHMT-1869.6.4.2, NHMT-1887.12.17.98, NHMT-1925.12.24.69, NHMT-1887.3.22.586, NHMT-1860.11.26.13, NHMT-1887.3.22.585, NHMT-1887.3.22.588
Heliodoxa jacula	ZFMK-8507, ZFMK-8509, ZFMK-8508, ZFMK-8511, ZFMK-87097, ZFMK-5911, ZFMK-8512, ZFMK-8505, ZFMK-87096, ZFMK-8504
Heliodoxa leadbeateri	ZFMK-8484, ZFMK-8487, ZFMK-8488, ZFMK-8491, ZFMK-8492, ZFMK-8494, ZFMK-8495, ZFMK-8496, ZFMK-8499, ZFMK-10273
Heliodoxa rubinoides	ZFMK-8480, ZFMK-8470, AMNH-124135, AMNH-166883, AMNH-124134, ZFMK-8476, ZFMK-8473, ZFMK-8468, ZFMK-10267, ZFMK-8472
Heliodoxa schreibersii	NHMT-1969.38.20, NHMT-1887.3.22.562, NHMT-1887.3.22.559, NHMT-1954.5.25.11, NHMT-1940.12.5.546, NHMT-NL (116), NHMT-1887.3.22.558, NHMT-NL (114), NHMT-1861.11.11.69, NHMT-NL (115)
Heliodoxa xanthogonys	AMNH-482731, AMNH-482730, AMNH-236597, AMNH-156066, AMNH-482729, AMNH-812877, AMNH-270496, AMNH-482732, AMNH-482733, AMNH-482728
Heliomaster constantii	ZFMK-9673, ZFMK-9674, AMNH-484516, ZFMK-9664, ZFMK-9666, ZFMK-9668, ZFMK-9670, ZFMK-9667, ZFMK-9671, USNM-309874
Heliomaster furcifer	ZFMK-9623, ZFMK-9620, MBML-1058, ZFMK-9622, ZFMK-9614, MBML-1506, ZFMK-9619, ZFMK-9615, ZFMK-63499, ZFMK-56166
Heliomaster longirostris	USNM-238443, USNM-201167, USNM-201171, USNM-201163, USNM-229312, ZFMK-9651, ZFMK-9642, ZFMK-B1155aE, ZFMK-9654, ZFMK-9655
Heliomaster squamosus	MNRJ-40768, MNRJ-40792, MNRJ-48198, MNRJ-40781, MNRJ-40776, MNRJ-40767, MNRJ-18691, MNRJ-40769, MNRJ-41920, MNRJ-40773
Heliothryx auritus	AMNH-130798, AMNH-431959, MNRJ-40317, MNRJ-40306, MNRJ-40322, MNRJ-40309, MNRJ-40313, MNRJ-40320, MNRJ-40310, MNRJ-40312
Heliothryx barroti	AMNH-46843, AMNH-77536, AMNH-135468, AMNH-246600, AMNH-247416, AMNH-389727, AMNH-389729, AMNH-389730, AMNH-484376, AMNH-484377
Hylocharis chrysura	AMNH-321568, AMNH-314104, MNRJ-36595, MNRJ-41643, MNRJ-41644, AMNH-314103, MNRJ-18339, MNRJ-41640, MNRJ-18340, MNRJ-41646
Hylocharis cyanus	MNRJ-41603, MNRJ-41616, MNRJ-41617, MNRJ-41601, MNRJ-41605, MNRJ-29777, MNRJ-32386, MNRJ-41602, MNRJ-41607, MNRJ-41611

Hylocharis eliciae	AMNH-95759, AMNH-95760, AMNH-95762, AMNH-99537, AMNH-99539, AMNH-389586, AMNH-389588, AMNH-389591, AMNH-480657, AMNH-480658
Hylocharis grayi	MBML-1603, ZFMK-3437, ZFMK-7438, ZFMK-7440, ZFMK-7441, ZFMK-7445, ZFMK-7447, ZFMK-7450, ZFMK-9191, ZFMK-9196
Hylocharis humboldtii	FMNH-19718, FMNH-45922, FMNH-50090, USNM-213171, USNM-386031, USNM-386032, USNM-386033, USNM-386034, USNM-442970, USNM-442972
Hylocharis sapphirina	MPEG-28414, MPEG-32370, MPEG-46775, MPEG-32618, MPEG-15520, MPEG-50532, MPEG-15599, MPEG-52289, MPEG-70132, MPEG-30731
Hylonympha macrocerca	AMNH-40461, AMNH-40464, AMNH-482735, AMNH-482737, NHMT-1887.3.22.951, NHMT-1887.3.22.952, NHMT-1887.3.22.954, NHMT-1887.3.22.955, NHMT-1988.21.45, NHMT-1988.21.46
Klais guimeti	AMNH-179071, AMNH-185010, AMNH-485059, AMNH-185009, AMNH-129532, AMNH-179068, AMNH-129535, AMNH-485055, AMNH-485058, AMNH-485056
Lafresnaya lafresnayi	SMF-87872, SMF-87874, SMF-87875, USNM-174283, USNM-174289, SMF-87871, SMF-87873, SMF-87876, SMF-87877, SMF-87878
Lampornis amethystinus	NHMT-1887.3.22.298, NHMT-1887.3.22.300, NHMT-1912.7.1.70, NHMT-1912.7.1.79, NHMT-NL (102), NHMT-1912.7.1.69, NHMT-1912.7.1.71, NHMT-1912.7.1.72, NHMT-1912.7.1.75, NHMT-1912.7.1.77
Lampornis calolaemus	FMNH-36139, FMNH-72235, FMNH-36138, FMNH-6755, FMNH-72233, FMNH-36140, FMNH-72232, FMNH-6756, AMNH-389721, AMNH-389714
Lampornis castaneoventris	ZFMK-8431, ZFMK-8429, ZFMK-8430, ZFMK-8428, AMNH-37242, ZFMK-8421, ZFMK-8419, ZFMK-8422, ZFMK-8424, ZFMK-8423
Lampornis cinereicauda	SMF-86862, SMF-86863, SMF-86865, SMF-86866, SMF-86868, SMF-86869, USNM-201142, USNM-201143, USNM-210493, USNM-309611
Lampornis clemenciae	ZFMK-198265, ZFMK-198266, ZFMK-8404, ZFMK-198268, ZFMK-8403, ZFMK-8398, ZFMK-8400, ZFMK-198260, ZFMK-8402, ZFMK-198261
Lampornis hemileucus	NHMT-1868.2.17.9, NHMT-1887.3.22.314, NHMT-1919.58.1177, USNM-110284, USNM-201152, NHMT-1865.5.19.17, NHMT-1887.3.22.316, NHMT-1949.58.1178, NHMT-NL (140), NHMT-NL (142)
Lampornis sybillae	AMNH-143888, FMNH-21913, FMNH-21918, FMNH-21919, FMNH-27489, FMNH-481715, FMNH-481716, FMNH-481717, FMNH-481718, FMNH-481719
Lampornis viridipallens	NHMT-1887.3.22.307, NHMT-1887.3.22.310, NHMT-1887.3.22.311, NHMT-1887.3.22.312, NHMT-

	1887.3.22.313, NHMT-60.11.20.45, NHMT-NL (1), NHMT-NL (2), NHMT-NL (3), NHMT-NL (4)
Lamprolaima rhami	NHMT-NL (5), NHMT-NL (7), NHMT-NL (9), NHMT-NL (8), NHMT-NL (6), NHMT-NL (14), NHMT-NL (11), NHMT-NL (10), NHMT-NL (13), NHMT-NL (12)
Lepidopyga coeruleogularis	MNRJ-42235, MNRJ-42236, NHMT-1887.3.14.469, NHMT-1887.3.22.2011, NHMT-1887.3.22.2013, NHMT-1887.3.22.2016, NHMT-1887.3.22.2017, NHMT-1887.3.22.2019, NHMT-1936.1.21.406, NHMT-1936.1.21.407, NHMT-1936.1.21.433
Lepidopyga goudoti	ZFMK-9088, ZFMK-9089, ZFMK-9093, ZFMK-9094, ZFMK-9096, ZFMK-9097, ZFMK-9098, ZFMK-9099, ZFMK-9100, ZFMK-9102
Lesbia nuna	ZMSNM-63608, ZMSNM-63607, ZMSNM-63604, ZMSNM-63602, ZMSNM-63603, ZMSNM-63597, ZMSNM-63595, ZMSNM-63591, ZMSNM-63592, ZMSNM-63596
Lesbia victoriae	ZFMK-9517, ZFMK-9526, ZFMK-9519, ZFMK-9520, ZFMK-9511, ZFMK-9524, ZFMK-9515, ZFMK-9522, ZFMK-9516, ZFMK-9498
Leucippus baeri	AMNH-151365, FMNH-91739
Leucippus chlorocercus	NHMT-1887.3.22.1690, AMNH-255302, MNRJ-48260, MNRJ-48262, MNRJ-48261, MNRJ-48259, AMNH-255303, MNRJ-48258, MNRJ-41970, MNRJ-48257
Leucippus fallax	AMNH-479634, AMNH-479638, AMNH-479639, AMNH-479640, AMNH-479642, AMNH-479643, AMNH-479644, AMNH-479646, AMNH-479647, AMNH-479648
Leucippus taczanowskii	NHMT-1902.3.13.1925, NHMT-1902.3.13.1926, NHMT-1902.3.13.1927, NHMT-1902.3.13.1928, NHMT-1912.7.1.300, NHMT-1912.7.1.301, NHMT-1912.7.1.302, NHMT-1912.7.1.303, NHMT-1912.7.1.304, NHMT-1912.7.1.305
Leucochloris albicollis	AMNH-316632, AMNH-314078, AMNH-316631, MNRJ-41519, MNRJ-41521, MNRJ-41508, MNRJ-41855, MNRJ-41518, MNRJ-41511, MNRJ-41549
Loddigesia mirabilis	AMNH-182362, AMNH-235495, AMNH-235497, AMNH-235503, AMNH-235504, AMNH-235505, AMNH-485348, AMNH-485351, AMNH-485353, AMNH-485354
Lophornis adorabilis	AMNH-77546, AMNH-485243, AMNH-485244, AMNH-485245, SMF-84023, SMF-84026, SMF-84027, SMF-84028, SMF-84029, SMF-84030
Lophornis chalybeus	NHMT-NL (21), NHMT-1895.4.1.109, NHMT-NL (20), NHMT-NL (18), NHMT-NL (19), NHMT-1895.4.1.1008, NHMT-NL (15), NHMT-1887.3.22.1286, NHMT-NL (16), NHMT-NL (17)
Lophornis delattrei	ZFMK-10074, ZFMK-10075, ZFMK-10076, ZFMK-10077, ZFMK-10079, ZFMK-10082, ZFMK-10083, ZFMK-10086, ZFMK-10089, ZFMK-54871

Lophornis gouldii	NHMT-NL (54), NHMT-NL (51), NHMT-NL (50), NHMT-NL (53), USNM-306052, USNM-306053, FMNH-63236, NHMT-NL (52), AMNH-485149, NHMT-1933.11.14.73
Lophornis helenae	AMNH-38033, AMNH-101202, AMNH-101203, AMNH-186612, AMNH-199258, AMNH-199259, AMNH-199265, AMNH-326304, AMNH-389781, AMNH-389782
Lophornis magnificus	MNRJ-48210, MNRJ-48209, MNRJ-48216, MNRJ-48213, MNRJ-48211, MNRJ-41856, MNRJ-41863, MNRJ-41858, MNRJ-41934, MNRJ-41861
Lophornis ornatus	AMNH-485124, AMNH-240871, AMNH-485110, AMNH-38021, AMNH-38025, AMNH-46325, AMNH-485120, AMNH-485114, AMNH-38023, AMNH-38074
Lophornis pavoninus	NHMT-1913.3.20.669, NHMT-NL (103), NHMT-1911.11.14.71, NHMT-1911.11.14.73, NHMT-1922.3.5.1163, NHMT-NL (104), AMNH-485251, NHMT-NL (105), NHMT-1913.3.20.667, NHMT-1887.3.22.1280
Lophornis stictolophus	NHMT-1940.12.5.572, NHMT-1940.12.5.574, NHMT-1940.12.5.575, NHMT-1940.12.5.578, NHMT-1940.12.5.581, NHMT-1940.12.5.582, NHMT-1940.12.5.583, NHMT-1940.12.5.584, NHMT-1969.37.41, NHMT-1969.37.43
Mellisuga helenae	ZFMK-9814, USNM-233776, USNM-309720, USNM-110682, USNM-233773, ZFMK-9818, ZFMK-9817, AMNH-484683, AMNH-60746, USNM-253723
Mellisuga minima	AMNH-484988, AMNH-37784, AMNH-46607, AMNH-46608, AMNH-484984, AMNH-484985, AMNH-484986, AMNH-37782, AMNH-37783, AMNH-46610
Metallura aeneocauda	AMNH-166522, NHMT-1887.3.22.1434, NHMT-1887.3.22.1435, NHMT-1887.3.22.1435B, NHMT-1913.3.20.445, NHMT-1946.9.9.254, NHMT-1949.9.9.204, NHMT-NL (22), NHMT-NL (23), NHMT-NL (24), NHMT-NL (25)
Metallura baroni	AMNH-483780, AMNH-483781, NHMT-1896.2.11.4, AMNH-182355, AMNH-483773, AMNH-483774, AMNH-483775, AMNH-483776, AMNH-483777, NHMT-1896.2.11.3
Metallura eupogon	AMNH-169608, AMNH-169610, AMNH-174045, AMNH-483770, AMNH-820739, AMNH-820741, AMNH-820742, AMNH-820743, NHMT-1887.3.22.1432, NHMT-1892.12.24.22
Metallura iracunda	USNM-372807, USNM-372808, USNM-372811, USNM-372814, USNM-372815, USNM-372816, USNM-372817, USNM-372820, USNM-372824, USNM-372825
Metallura odomae	FMNH-222236, FMNH-222237, USNM-586243
Metallura phoebe	AMNH-483741, NHMT-1902.3.13.2071, NHMT-1902.3.13.2072, NHMT-1902.3.13.2073, NHMT-1902.3.13.2074, NHMT-1902.3.13.2075, NHMT-

	1912.12.31.24, NHMT-1912.7.1.137, NHMT-1912.7.1.138, NHMT-1912.7.1.140
Metallura theresiae	FMNH-299102, AMNH-234454, AMNH-234455, AMNH-781692, FMNH-44647, ZMSNM-103138, ZMSNM-103139, ZMSNM-103140, ZMSNM-103141, ZMSNM-103142, ZMSNM-103143
Metallura tyrianthina	ZFMK-9222, ZFMK-9223, ZFMK-9225, ZFMK-9226, ZFMK-9224, ZFMK-9217, ZFMK-9214, ZFMK-9215, ZFMK-9216, ZFMK-5915
Metallura williami	ZFMK-9175, ZFMK-9176, ZFMK-9177, ZFMK-9178, ZFMK-9179, ZFMK-9180, ZFMK-9181, ZFMK-9182, ZFMK-9184, ZFMK-9185
Microchera albocoronata	AMNH-99575, AMNH-389778, NHMT-1887.3.22.1040, NHMT-1887.3.22.1041, NHMT-1949.58.1255, NHMT-1960.6.30.59, NHMT-1969.25.692, NHMT-1969.25.693, NHMT-1992.3.19, NHMT-NL (26)
Microstilbon burmeisteri	FMNH-179492, AMNH-484842, AMNH-484845, FMNH-65515, FMNH-65517, FMNH-65519, FMNH-66328, FMNH-179490, FMNH-179491, FMNH-179494, FMNH-293745
Myrmia micrura	NHMT-1897.11.12.130, NHMT-1902.3.13.2199, NHMT-1902.3.13.2200, NHMT-1902.3.13.2201, NHMT-1912.7.1.197, NHMT-1912.7.1.198, NHMT-1912.7.1.199, NHMT-1912.7.1.200, NHMT-1912.7.1.201, NHMT-1912.7.1.203
Myrtis fanny	AMNH-37974, AMNH-151456, AMNH-170367, AMNH-170368, AMNH-170370, AMNH-175193, AMNH-235489, AMNH-235490, AMNH-235491, AMNH-484535
Ocreatus underwoodii	ZFMK-9682, ZFMK-9665, ZFMK-9669, ZFMK-9678, ZFMK-9662, ZFMK-9675, ZFMK-9666, ZFMK-9676, ZFMK-9668, ZFMK-9671
Opisthoprora euryptera	NHMT-1887.3.22.1428, NHMT-1887.3.22.1429, NHMT-1913.3.20.439, NHMT-1913.3.20.440, NHMT-1913.3.20.441, NHMT-1913.3.20.445, NHMT-2002.3.887, NHMT-2002.3.888, NHMT-2002.3.889, NHMT-2002.3.890
Oreonympha nobilis	NHMT-1946.49.392, NHMT-1946.49.396, NHMT-1946.49.391, NHMT-1946.49.387, NHMT-1946.49.397, NHMT-1946.49.394, NHMT-1946.49.390, NHMT-1946.49.389, NHMT-1946.49.388, NHMT-1946.49.395
Oreotrochilus adela	NHMT-1887.3.14.80, NHMT-1887.3.22.377, NHMT-1887.3.22.378, NHMT-1902.3.13.2008, NHMT-1902.3.13.2009, NHMT-1902.3.13.2010, NHMT-1902.3.13.2011, NHMT-NL (27), NHMT-NL (28), NHMT-NL (29)
Oreotrochilus chimborazo	SMF-87241, SMF-87244, SMF-87245, SMF-87248, SMF-87249, SMF-87250,SMF-87256, SMF-87261, SMF-87264, ZMSNM-62973, ZMSNM-62975

Oreotrochilus estella	AMNH-37261, AMNH-229175, AMNH-482475, AMNH-482479, AMNH-482480, ZFMK-8337, ZFMK-8338, ZFMK-8339, ZFMK-8342, ZFMK-81402
Orthorhyncus cristatus	ZFMK-10019, ZFMK-10017, ZFMK-10018, ZFMK-10005, ZFMK-10013, ZFMK-10012, ZFMK-10014, ZFMK-10008, USNM-231768, USNM-231763
Panterpe insignis	AMNH-153955, AMNH-389621, AMNH-38454, AMNH-389607, AMNH-821350, AMNH-389616, AMNH-153952, AMNH-389618, AMNH-389617, AMNH-209642
Phaeochroa cuvierii	NHMT-1912.7.1.299, NHMT-NL (40), NHMT-1912.7.1.296, NHMT-1912.7.1.293, NHMT-1912.7.1.294, NHMT-1912.7.1.297, NHMT-1887.3.22.280, NHMT-1912.7.1.295, NHMT-NL (42), NHMT-NL (41)
Phaethornis bourcieri	MPEG-63707, MPEG-58008, MPEG-52716, MPEG-52033, MPEG-69986, AMNH-816626, MPEG-60487, MPEG-MG 59922, MPEG-52032, MPEG-52549
Phaethornis eurynome	MPEG-27719, MPEG-27722, MPEG-27720, MPEG-MG 40969, MPEG-27717, MPEG-27718, MPEG-28002, MPEG-27723, MPEG-28003, MPEG-27721
Phaethornis gounellei	MPEG-76741, MPEG-MG 67.907, MPEG-76740, MPEG-76790, MNRJ-32153, MNRJ-17965, MNRJ-32119, MPEG-75488, MPEG-75492, MNRJ-43404
Phaethornis guy	ZFMK-6729, ZFMK-6730, ZFMK-6720, ZFMK-6721, ZFMK-6725, ZFMK-6726, ZFMK-6717, ZFMK-6724, ZFMK-6718, ZFMK-6727
Phaethornis hispidus	AMNH-178987, AMNH-178988, AMNH-185162, AMNH-255281, AMNH-237853, MPEG-63627, MPEG-60490, MPEG-63706, MPEG-MG 59925, MPEG-60489
Phaethornis longirostris	AMNH-479181, AMNH-479193, AMNH-37114, AMNH-479177, AMNH-479186, AMNH-479189, AMNH-313431, AMNH-479185, AMNH-479187, AMNH-479188
Phaethornis longuemareus	AMNH-46234, AMNH-37093, AMNH-393932, AMNH-393930, AMNH-393934, AMNH-393931, AMNH-393933, AMNH-393929, AMNH-37089, AMNH-393935
Phaethornis malaris	MPEG-72745, MPEG-42998, MPEG-42469, MPEG-42470, MPEG-42471, AMNH-233749, MPEG-72815, MPEG-72814, MPEG-42468, MPEG-42467
Phaethornis pretrei	AMNH-798780, AMNH-837266, AMNH-127386, AMNH-479056, MNRJ-34378, MNRJ-43775, MNRJ-43779, MNRJ-43785, MNRJ-34319, MNRJ-43780
Phaethornis ruber	MPEG-26409, MPEG-27835, MPEG-47365, MPEG-22112, MPEG-32312, MPEG-35218, MPEG-25103, MPEG-72454, MPEG-33319, MPEG-66623
Phaethornis squalidus	MNRJ-43817, MNRJ-43829, MNRJ-43830, MNRJ-43825, MNRJ-43821, MNRJ-43819, MNRJ-43820, MNRJ-43818, MNRJ-43815, MNRJ-43826

Phaethornis striigularis	MNRJ-41936, MNRJ-41940, MNRJ-41937, MNRJ-41935, MNRJ-42272, MNRJ-42277, MNRJ-42275, MNRJ-42274, MNRJ-42278, MNRJ-42279
Phaethornis stuarti	AMNH-148263, AMNH-148266, AMNH-479249, AMNH-138655, AMNH-148264, AMNH-479246, AMNH-479247, AMNH-479248, AMNH-818053, AMNH-818054
Phaethornis subochraceus	AMNH-127387, AMNH-149425, FMNH-334396, FMNH-334979, FMNH-65390, FMNH-334394, FMNH-334981
Phaethornis superciliosus	MPEG-77589, MPEG-62437, MPEG-77515, MPEG-77516, MPEG-77281, AMNH-275977, AMNH-821442, AMNH-434084, MPEG-62435, MPEG-62442
Phaethornis syrmatophorus	AMNH-478982, AMNH-175925, AMNH-115811, AMNH-478978, AMNH-175923, AMNH-175921, AMNH-478975, AMNH-179990, AMNH-185156, AMNH-478974
Polytmus guainumbi	MBML-783, MBML-786, MNRJ-39845, MNRJ-39844, MNRJ-18743, MBML-1621, MBML-1622, MNRJ-39846, MNRJ-24865, MNRJ-18745
Pterophanes cyanopterus	ZMSNM-63049, ZMSNM-63050, ZMSNM-63047, ZMSNM-63046, ZMSNM-63048, ZMSNM-63039, ZMSNM-63041, ZMSNM-63042, ZMSNM-63040, ZMSNM-16121926
Ramphodon naevius	MNRJ-40885, MNRJ-40883, MNRJ-40926, MNRJ-40895, MNRJ-40886, MNRJ-40875, MNRJ-40868, MNRJ-40887, MNRJ-40878, MNRJ-40898
Ramphomicron microrhynchum	ZMSNM-63652, ZMSNM-63649, ZMSNM-63653, ZMSNM-63647, ZMSNM-63651, ZMSNM-63626, ZMSNM-63616, ZMSNM-63627, ZMSNM-63615, ZMSNM-63622
Selasphorus flammula	USNM-208727, USNM-208724, USNM-208729, USNM-199756, USNM-199456, USNM-208728, USNM-208721, USNM-208726, USNM-208722, USNM-200332
Selasphorus platycercus	USNM-300272, USNM-203596, USNM-154821, USNM-69134, USNM-140303, USNM-140307, USNM-140323, USNM-241342, USNM-140308, USNM-140305
Selasphorus rufus	AMNH-87492, AMNH-361609, AMNH-361706, AMNH-361736, AMNH-361928, AMNH-49367, AMNH-754675, AMNH-49364, AMNH-361739, AMNH-754152
Selasphorus sasin	USNM-529144, USNM-170655, USNM-462930, USNM-563186, USNM-170656, USNM-134374, USNM-203259, USNM-203258, USNM-134375, USNM-190970
Selasphorus scintilla	ZFMK-9871, ZFMK-9887, ZFMK-9872, ZFMK-9884, ZFMK-9882, ZFMK-9884, ZFMK-9874, ZFMK-9877, ZFMK-9875, ZFMK-9873
Stellula calliope	USNM-230582, USNM-94863, USNM-77446, USNM-259620, USNM-269471, USNM-228163, USNM-228164, USNM-228168, USNM-228170, USNM-228167
Stephanoxis lalandi	MNRJ-40253, MNRJ-40247, MNRJ-40252, MNRJ-40234, MNRJ-40251, MNRJ-40210, MNRJ-40243, MNRJ-40212, MNRJ-40242, MNRJ-40237

Thalurania colombica	USNM-163212, USNM-253382, USNM-368825, USNM-149043, USNM-47602, USNM-368774, USNM-372861, USNM-127651, USNM-47858, USNM-446284
Thalurania furcata	MPEG-34537, MPEG-65734, MPEG-64603, MPEG-66423, MPEG-61005, MPEG-34536, MPEG-34538, MPEG-66627, MPEG-64602, MPEG-64964
Thalurania glaucopis	MPEG-27890, MPEG-27630, MPEG-27892, MPEG-27903, MPEG-27902, MPEG-27627, MPEG-25414, MPEG-27888, MPEG-27588, MPEG-27579
Threnetes leucurus	MPEG-52037, MPEG-63704, MPEG-63703, MPEG-63261, MPEG-69984, MPEG-63701, MPEG-52038, MPEG-52039, MPEG-52040, MPEG-63702
Threnetes ruckeri	USNM-606088, USNM-606760, USNM-606087, USNM-606085, USNM-606086, USNM-606077, USNM-606075, USNM-606078, USNM-606079, USNM-606080
Topaza pyra	AMNH-434189, AMNH-802114, NHMT-1997.16.4, MNRJ-41776, NHMT-1997.16.6, NHMT-1997.16.3, NHMT-1997.16.5, NHMT-1997.16.1, ZFMK-8306, NHMT-1888.7.25.158
Trochilus polytmus	ZFMK-81341, ZFMK-87016, ZFMK-87019, ZFMK-87018, ZFMK-88007, ZFMK-96057, ZFMK-96056, ZFMK-87014, ZFMK-87013, ZFMK-84115
Urosticte benjamini	ZMSNM-62906, ZMSNM-62902, ZMSNM-62899, ZMSNM-62897, ZMSNM-62908, ZMSNM-62880, ZMSNM-62877, ZMSNM-62885, ZMSNM-62881, ZMSNM-62886

APPENDIX S4 – INSERTION METHODS OF SPECIES MISSING IN THE PHYLOGENY OF MCGUIRE ET AL. (2014)

Sixty hummingbird species (17%) of the total extant hummingbird fauna (n=343, Gill & Donsker 2014) were not included in the most comprehensive dated phylogeny available (McGuire et al. 2014, Table S2). Using McGuire et al. (2014) as a backbone phylogeny in the SUNPLIN software, we inserted the missing species with branch-based insertion methods (Martins et al. 2013). We developed four criteria for the insertion of missing species: (1) If the missing species belongs to a monophyletic genus, it was included in the most derived node including all the species of the given genus; (2) if the missing species belongs to a polyphyletic genus, it was included in the most derived node including the most taxonomic related species; (3) if the missing species belongs to a genus that contains only one species in the phylogeny, it was included as a sister clade of the given species; (4) if the missing species belongs to a genus that is not included in the phylogeny, it was included as a sister clade of the most taxonomic related species. Descriptions of the node of insertion and the source describing the taxonomic relations of each missing species can be found in the Table S2.

Table S2 – Node of insertion of 60 hummingbird species that were not included in McGuire et al. (2014) phylogeny; MDN – "most derived node" that includes the cited species and species of the same genus; SC – sister clade.

Species	**Node of insertion**	**Taxonomic source**
Aglaeactis aliciae	*Aglaeactis* genus	-
Aglaiocercus berlepschi	*Aglaiocercus* genus	-
Amazilia boucardi	MDN of *Amazilia rosenbergi*	1
Amazilia cyanifrons	MDN of *Amazilia saucerottei*	1
Amazilia luciae	MDN of *Amazilia rosenbergi*	1
Amazilia wagneri	MDN of *Amazilia viridifrons*	1
Anopetia gounellei	*Phaethornis* genus	2
Atthis ellioti	SC of *Atthis heloisa*	-
Augastes lumachella	SC of *Schistes geoffroyi*	3
Augastes scutatus	SC of *Schistes geoffroyi*	3
Calothorax pulcher	SC of *Calothorax pulcher*	-
Campylopterus curvipennis	MDN of *Campylopterus excellens*	4
Campylopterus pampa	MDN of *Campylopterus excellens*	4
Campylopterus phainopeplus	*Campylopterus* genus	4
Chaetocercus astreans	SC of *Chaetocercus bombus*	-
Chaetocercus berlepschi	SC of *Chaetocercus bombus*	-
Chaetocercus heliodor	SC of *Chaetocercus bombus*	-
Chaetocercus jourdanii	SC of *Chaetocercus bombus*	-
Chalcostigma heteropogon	SC of *Chalcostigma herrani*	-
Chlorostilbon alice	MDN of *Chlorostilbon poortmani*	4
Chlorostilbon auriceps	MDN of *Chlorostilbon mellisugus*	4
Chlorostilbon forficatus	MDN of *Chlorostilbon mellisugus*	4
Chlorostilbon gibsoni	MDN of *Chlorostilbon mellisugus*	4
Chlorostilbon olivaresi	MDN of *Chlorostilbon mellisugus*	4
Chlorostilbon russatus	*Chlorostilbon* genus	4
Chlorostilbon stenurus	MDN of *Chlorostilbon poortmani*	4
Discosura letitiae	*Discosura* genus	-
Doricha enicura	SC of *Doricha eliza*	-
Eriocnemis godini	MDN of *Eriocnemis cupreioventris*	4
Eriocnemis isabellae	MDN of *Eriocnemis vestitus*	4
Eriocnemis mirabilis	MDN of *Eriocnemis alinae*	4
Glaucis dohrnii	*Glaucis* genus	-
Haplophaedia assimilis	*Haplophaedia* genus	-
Heliangelus mavors	MDN of *Heliangelus regalis*	5
Hylocharis humboldtii	SC of *Hylocharis grayi*	-
Hylonympha macrocerca	SC of *Eugenes fulgens*	6
Lepidopyga lilliae	SC of *Lepidopyga coeruleogularis*	-
Lophornis adorabilis	*Lophornis* genus	-
Lophornis brachylophus	*Lophornis* genus	-
Lophornis gouldii	*Lophornis* genus	-
Lophornis helenae	*Lophornis* genus	-
Lophornis magnificus	*Lophornis* genus	-

Lophornis ornatus	*Lophornis* genus	-
Lophornis stictolophus	*Lophornis* genus	-
Mellisuga helenae	SC of *Mellisuga minima*	-
Metallura iracunda	*Metallura* genus	-
Oreotrochilus adela	*Oreotrochilus* genus	-
Oreotrochilus leucopleurus	*Oreotrochilus* genus	-
Oxypogon cyanolaemus	SC of *Oxypogon guerinii*	-
Oxypogon lindenii	SC of *Oxypogon guerinii*	-
Oxypogon stuebelii	SC of *Oxypogon guerinii*	-
Phaethornis aethopygus	*Pygmornis* subgenus	2
Phaethornis idaliae	*Pygmornis* subgenus	2
Phaethornis squalidus	SC of *Pygmornis* subgenus	2
Phaethornis stuarti	*Pygmornis* subgenus	2
Phlogophilus hemileucurus	*Phlogophilus harteri*	-
Ramphomicron dorsale	SC of *Ramphomicron microrhynchum*	-
Selasphorus ardens	MDN of *Selasphorus scintilla*	3
Sternoclyta cyanopectus	SC of *Eugenes fulgens*	6
Threnetes niger	*Threnetes* genus	-

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APPENDIX S5 – TRAIT DISTRIBUTION AMONG THREATENED AND NON-THREATENED HUMMINGBIRD SPECIES

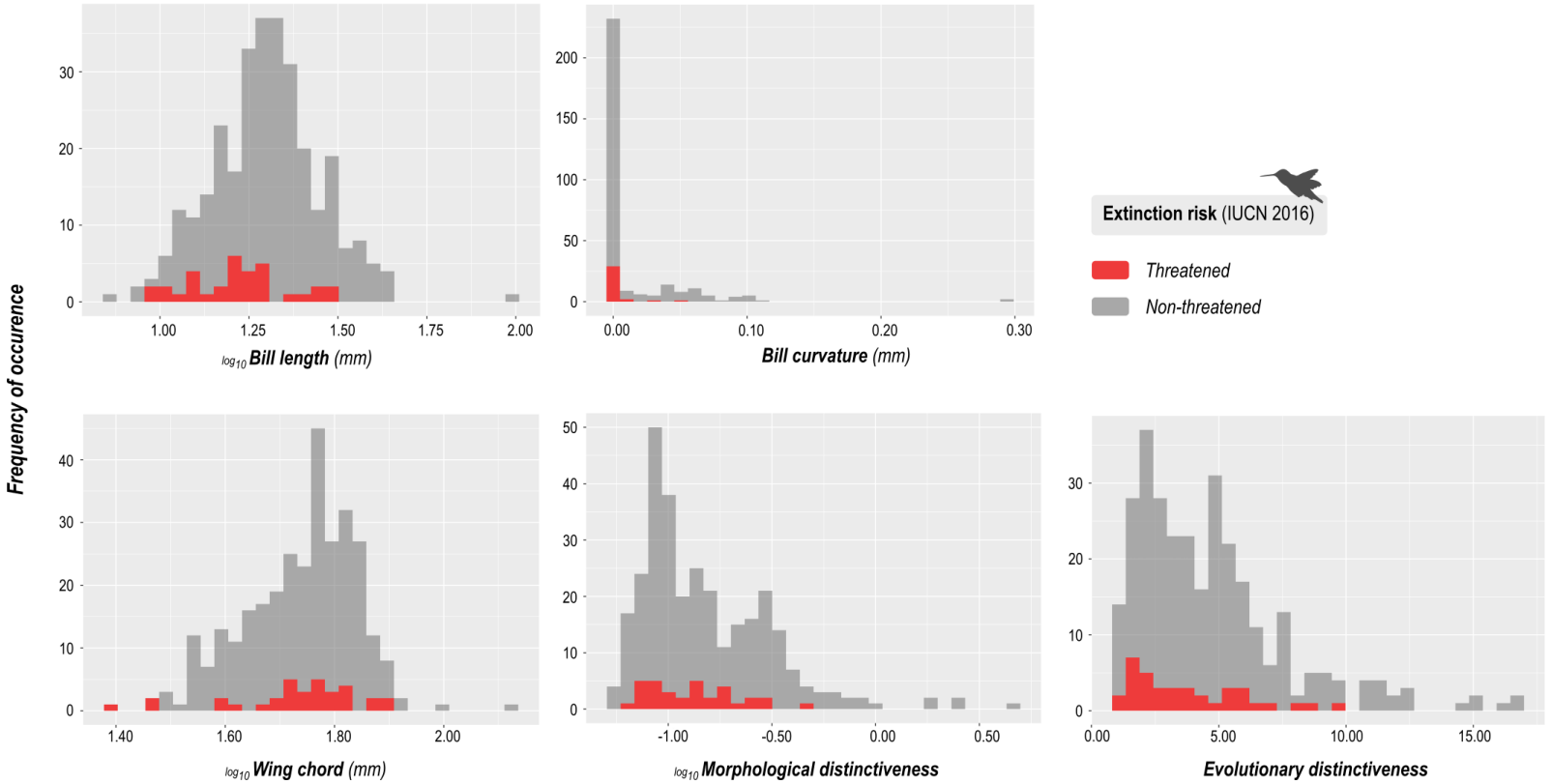

Figure S1 – Distribution of the morphological and evolutionary traits of threatened and non-threatened hummingbirds.

APPENDIX S6 – MORPHOLOGICAL AND EVOLUTIONARY DISTINCTIVENESS OF HUMMINGBIRDS

Table S3 – Morphological and evolutionary distinctiveness of hummingbirds and its corresponding extinction risk status (IUCN 2016). In bold species with the highest 10% values of morphological and evolutionary distinctiveness. NM – not available for measurements at the visited museums.

Species	Morphological distinctiveness	Evolutionary distinctiveness	Extinction risk status
Abeillia abeillei	0.167509635	7.183381432	Least concern
Adelomyia melanogenys	0.120771614	**9.027050194**	Least concern
*Aglaeactis aliciae**	**0.447731712**	3.620877611	Endangered
Aglaeactis castelnaudii	0.121601256	3.754090611	Least concern
Aglaeactis cupripennis	0.278279374	4.278158611	Least concern
Aglaeactis pamela	0.14674394	3.620877611	Least concern
Aglaiocercus berlepschi	0.092144341	4.248855361	Endangered
Aglaiocercus coelestis	0.118331236	4.248855361	Least concern
Aglaiocercus kingii	0.083134555	4.572553861	Least concern
Amazilia amabilis	0.056605275	2.568280616	Least concern
Amazilia amazilia	0.058445441	4.426859739	Least concern
Amazilia beryllina	0.085413743	1.38506622	Least concern
Amazilia boucardi	0.096530623	2.568280616	Endangered
Amazilia brevirostris	0.060106213	1.375729151	Least concern
Amazilia candida	0.086555067	3.9018951	Least concern
Amazilia castaneiventris	0.065492625	1.40065347	Endangered
Amazilia chionogaster	0.098793529	2.860898495	Least concern
Amazilia cyanifrons	0.075164429	1.26232872	Least concern
Amazilia cyanocephala	0.062968162	2.10108297	Least concern
Amazilia cyanura	0.06124141	1.38506622	Least concern
Amazilia decora	0.09056968	2.58828995	Least concern
Amazilia edward	0.075169473	1.85320247	Least concern
Amazilia fimbriata	0.056605275	2.246636995	Least concern
Amazilia franciae	0.105315419	3.661079539	Least concern
Amazilia lactea	0.06124141	2.246636995	Least concern
Amazilia leucogaster	0.105315419	1.375729151	Least concern
Amazilia luciae	NM	2.576855616	Endangered
Amazilia rosenbergi	0.09056968	2.7177007	Least concern
Amazilia rutila	0.107025947	5.518047015	Least concern
Amazilia saucerottei	0.090488758	1.26232872	Least concern
Amazilia tobaci	0.074892601	1.30563697	Least concern
Amazilia tzacatl	0.09745859	4.465022015	Least concern

Amazilia versicolor	0.071559923	2.485960651	Least concern
Amazilia violiceps	0.090359438	2.041020692	Least concern
Amazilia viridicauda	0.080897479	2.860898495	Least concern
Amazilia viridifrons	0.090359438	2.101870192	Least concern
Amazilia viridigaster	0.065492625	1.30563697	Least concern
Amazilia wagneri	0.080897479	2.041020692	Least concern
Amazilia yucatanensis	0.081350844	4.465022015	Least concern
Androdon aequatorialis	**0.360537052**	**15.14021898**	Least concern
Anopetia gounellei	**0.617998124**	2.249441713	Least concern
Anthocephala floriceps	0.109796311	6.186068432	Vulnerable
Anthracothorax dominicus	0.226589022	5.107840849	Least concern
Anthracothorax mango	0.242206325	5.914039474	Least concern
Anthracothorax nigricollis	0.13391831	4.998015599	Least concern
Anthracothorax prevostii	0.183836637	3.079873932	Least concern
Anthracothorax veraguensis	0.226625256	3.079873932	Least concern
Anthracothorax viridigula	0.319996205	3.583500932	Least concern
Anthracothorax viridis	0.24607613	4.360259515	Least concern
Aphantochroa cirrochloris	0.078515163	5.999445807	Least concern
Archilochus alexandri	0.172613081	2.624782878	Least concern
Archilochus colubris	0.082765189	2.624782878	Least concern
Atthis ellioti	0.091815136	1.203028769	Least concern
Atthis heloisa	0.103837183	1.203028769	Least concern
Augastes lumachella	0.07814702	**11.52420345**	Near threatened
Augastes scutatus	0.094206944	**10.61290045**	Near threatened
Avocettula recurvirostris	0.10503541	**10.55370064**	Least concern
Basilinna leucotis	0.075164429	6.877721531	Least concern
Basilinna xantusii	0.074122095	6.877721531	Least concern
Boissonneaua flavescens	0.139540266	5.808146913	Least concern
Boissonneaua jardini	0.121601256	6.337611913	Least concern
Boissonneaua matthewsii	0.139540266	5.808146913	Least concern
Calliphlox amethystina	0.121556303	3.709747339	Least concern
Calliphlox bryantae	0.068572589	1.810001618	Least concern
Calliphlox evelynae	0.323022494	3.617702878	Least concern
Calliphlox mitchellii	0.108561328	1.810001618	Least concern
Calothorax lucifer	0.291742124	1.849891778	Least concern
Calothorax pulcher	**0.344283398**	1.849891778	Least concern
Calypte anna	0.072967172	2.493558025	Least concern
Calypte costae	0.141597177	2.493558025	Least concern
Campylopterus curvipennis	0.201272603	4.923205751	Least concern
Campylopterus duidae	0.099119578	3.460662799	Least concern
Campylopterus ensipennis	**0.5920185**	5.021782232	Near threatened
Campylopterus excellens	0.194861938	4.923205751	Least concern

Campylopterus falcatus	0.183836637	5.021782232	Least concern
Campylopterus hemileucurus	**0.799222975**	5.813126799	Least concern
Campylopterus hyperythrus	0.083213631	3.460662799	Least concern
Campylopterus largipennis	0.149173571	4.279743132	Least concern
Campylopterus pampa	0.099084021	4.923205751	Least concern
Campylopterus phainopeplus	0.240656422	4.279743132	Endangered
Campylopterus rufus	0.169625925	4.923205751	Least concern
Campylopterus villaviscensio	0.201272603	5.984494732	Near threatened
Chaetocercus astreans	0.157826744	1.188048344	Least concern
Chaetocercus berlepschi	0.126998722	1.296474594	Endangered
Chaetocercus bombus	0.133249601	1.478789261	Vulnerable
Chaetocercus heliodor	0.165818604	1.029740344	Least concern
Chaetocercus jourdanii	0.103532803	1.391774344	Least concern
Chaetocercus mulsant	0.129837109	1.296474594	Least concern
Chalcostigma herrani	0.189741885	5.212862567	Least concern
Chalcostigma heteropogon	0.176083925	5.212862567	Least concern
Chalcostigma olivaceum	**0.447731712**	5.147054817	Least concern
Chalcostigma ruficeps	0.158760697	5.147054817	Least concern
Chalcostigma stanleyi	0.176083925	4.29554225	Least concern
Chalybura buffonii	0.24607613	4.861589233	Least concern
Chalybura urochrysia	0.13391831	4.861589233	Least concern
Chlorestes notata	0.072967172	2.9033921	Least concern
Chlorostilbon alice	0.080948896	2.595919803	Least concern
Chlorostilbon assimilis	0.070345656	1.925851755	Least concern
Chlorostilbon auriceps	0.144119611	2.631692303	Least concern
Chlorostilbon canivetii	0.070345656	2.941501172	Least concern
Chlorostilbon forficatus	0.091919865	1.925851755	Least concern
Chlorostilbon gibsoni	0.084465228	3.718604303	Least concern
Chlorostilbon lucidus	0.084862926	2.595919803	Least concern
Chlorostilbon maugaeus	0.094740229	4.831339672	Least concern
Chlorostilbon melanorhynchus	0.077203597	2.499181755	Least concern
Chlorostilbon mellisugus	0.068572589	1.567593636	Least concern
Chlorostilbon olivaresi	NM	1.734087636	Least concern
Chlorostilbon poortmani	0.082765189	3.521713089	Least concern
Chlorostilbon ricordii	0.068397964	5.580067339	Least concern
Chlorostilbon russatus	0.081808794	3.729456589	Least concern
Chlorostilbon stenurus	0.141597177	1.567593636	Least concern
Chlorostilbon swainsonii	0.080840664	4.831339672	Least concern
Chrysolampis mosquitus	0.120771614	7.51971514	Least concern
Chrysuronia oenone	0.084724753	2.170557151	Least concern
Clytolaema rubricauda	0.14674394	**8.899913501**	Least concern
Coeligena bonapartei	0.162700403	2.347112562	Least concern

Coeligena coeligena	0.125510811	6.655105836	Least concern
Coeligena helianthea	0.125510811	2.347112562	Least concern
Coeligena iris	0.256309597	4.478425812	Least concern
Coeligena lutetiae	0.277509703	2.536530062	Least concern
Coeligena orina	0.184798036	2.536530062	Critically endangered
Coeligena phalerata	0.207793136	3.759736812	Least concern
Coeligena prunellei	0.221494291	6.968359336	Vulnerable
Coeligena torquata	0.277509703	6.926023836	Least concern
Coeligena violifer	0.326088692	5.785673978	Least concern
Coeligena wilsoni	0.158218283	6.655105836	Least concern
Colibri coruscans	0.161687231	7.743053119	Least concern
Colibri delphinae	0.13620573	7.415498119	Least concern
Colibri serrirostris	0.076171772	**8.734704452**	Least concern
Colibri thalassinus	0.278585623	7.415498119	Least concern
Cyanophaia bicolor	0.099743287	5.427724672	Least concern
Cynanthus doubledayi	0.10635547	2.941501172	Least concern
Cynanthus latirostris	0.118884741	3.816588672	Least concern
Cynanthus sordidus	0.09745859	7.302534233	Least concern
Damophila julie	0.077203597	2.9033921	Least concern
Discosura conversii	0.098072678	4.832719679	Least concern
Discosura langsdorffi	0.103837183	3.580088679	Least concern
Discosura longicaudus	0.157572458	6.200988345	Least concern
Discosura popelairii	0.109242682	3.580088679	Near threatened
Doricha eliza	0.261276557	2.078586278	Near threatened
Doricha enicura	0.264432105	2.078586278	Least concern
Doryfera johannae	0.251526359	**9.889953309**	Least concern
Doryfera ludovicae	0.312650429	**9.889953309**	Least concern
Elvira chionura	0.096224383	2.093923899	Least concern
Elvira cupreiceps	**0.721548764**	2.093923899	Least concern
Ensifera ensifera	**4.784842751**	**11.20956258**	Least concern
Eriocnemis aline	0.071559923	5.607875997	Least concern
Eriocnemis cupreoventris	0.075014802	4.376700664	Near threatened
Eriocnemis derbyi	0.063788554	4.966099164	Near threatened
Eriocnemis glaucopoides	0.075169473	6.404673497	Least concern
Eriocnemis godini	0.075107029	4.376700664	Critically endangered
Eriocnemis isabellae	NM	3.137352997	Critically endangered
Eriocnemis luciani	0.076171772	5.293878497	Least concern
Eriocnemis mirabilis	0.079390808	5.607875997	Critically endangered
Eriocnemis mosquera	0.138842107	3.137352997	Least concern
Eriocnemis nigrivestis	0.099743287	3.520070997	Critically endangered
Eriocnemis vestita	0.078509097	3.520070997	Least concern
Eugenes fulgens	0.149173571	4.947320452	Least concern

Eulampis holosericeus	**0.430536301**	3.629217015	Least concern
Eulampis jugularis	**0.799222975**	3.629217015	Least concern
Eulidia yarrellii	0.315269903	2.079264896	Critically endangered
Eupetomena macroura	0.218860069	5.999445807	Least concern
Eupherusa cyanophrys	0.07814702	2.260390073	Endangered
Eupherusa eximia	0.094206944	2.434382573	Least concern
Eupherusa nigriventris	0.091919865	2.434382573	Least concern
Eupherusa poliocerca	0.075107029	2.260390073	Vulnerable
Eutoxeres aquila	**2.369953619**	**16.67116004**	Least concern
Eutoxeres condamini	**2.369953619**	**16.67116004**	Least concern
Florisuga fusca	0.183991936	**12.60691399**	Least concern
Florisuga mellivora	0.121124118	**12.60691399**	Least concern
Glaucis aeneus	**0.617998124**	6.260755832	Least concern
Glaucis dohrnii	0.312691877	5.167240832	Endangered
Glaucis hirsutus	**0.695645662**	5.167240832	Least concern
Goethalsia bella	0.079390808	3.392626423	Near threatened
Goldmania violiceps	0.088309397	3.392626423	Least concern
Haplophaedia assimilis	0.096040196	4.649762997	Least concern
Haplophaedia aureliae	0.089839172	4.890355497	Least concern
Haplophaedia lugens	0.100007643	4.649762997	Near threatened
Heliactin bilophus	0.149802013	**16.05947231**	Least concern
Heliangelus amethysticollis	0.118331236	4.961077661	Least concern
Heliangelus exortis	0.084003652	3.294418411	Least concern
Heliangelus mavors	0.109318473	2.900691911	Least concern
Heliangelus micraster	0.084003652	2.900691911	Least concern
Heliangelus regalis	0.125648403	7.873903228	Endangered
Heliangelus strophianus	0.105291706	5.492784061	Least concern
Heliangelus viola	0.083134555	4.759100411	Least concern
Heliodoxa aurescens	0.058445441	**8.899913501**	Least concern
Heliodoxa branickii	0.152356235	6.076123334	Least concern
Heliodoxa gularis	0.158659271	6.076123334	Vulnerable
Heliodoxa imperatrix	0.169625925	6.348499751	Least concern
Heliodoxa jacula	0.099119578	5.482417751	Least concern
Heliodoxa leadbeateri	0.084311998	5.482417751	Least concern
Heliodoxa rubinoides	0.106578061	6.348499751	Least concern
Heliodoxa schreibersii	0.099084021	**10.870895**	Least concern
Heliodoxa xanthogonys	0.075014802	8.046852334	Least concern
Heliomaster constantii	0.305442651	6.413457669	Least concern
Heliomaster furcifer	0.29730748	4.986838002	Least concern
Heliomaster longirostris	0.312650429	6.059543002	Least concern
Heliomaster squamosus	0.325672316	4.986838002	Least concern
Heliothryx auritus	0.144430594	**9.045697476**	Least concern

Heliothryx barroti	0.13620573	**9.045697476**	Least concern
Hylocharis chrysura	0.081350844	3.048327995	Least concern
Hylocharis cyanus	0.060106213	3.1912946	Least concern
Hylocharis eliciae	0.084862926	3.5400486	Least concern
Hylocharis grayi	0.094533423	1.879641151	Least concern
Hylocharis humboldtii	0.062968162	1.879641151	Least concern
Hylocharis sapphirina	0.065094453	3.048327995	Least concern
Hylonympha macrocerca	0.145510756	5.174328952	Endangered
Klais guimeti	0.088872886	7.183381432	Least concern
Lafresnaya lafresnayi	**0.430536301**	**12.19039761**	Least concern
Lampornis amethystinus	0.137565084	5.253535837	Least concern
Lampornis calolaemus	0.063788554	2.262841604	Least concern
Lampornis castaneoventris	0.082026804	2.262841604	Least concern
Lampornis cinereicauda	0.103699785	2.291636104	Least concern
Lampornis clemenciae	0.218860069	6.006027504	Least concern
Lampornis hemileucus	0.065985259	**9.752276646**	Least concern
Lampornis sybillae	0.105538486	3.869730437	Least concern
Lampornis viridipallens	0.100007643	3.869730437	Least concern
Lamprolaima rhami	0.109343308	**8.687543619**	Least concern
Lepidopyga coeruleogularis	0.062958544	1.603220151	Least concern
Lepidopyga goudoti	0.151290909	2.170557151	Least concern
Lepidopyga lilliae	NM	1.603220151	Critically endangered
Lesbia nuna	0.225770527	5.165925175	Least concern
Lesbia victoriae	0.109318473	5.165925175	Least concern
Leucippus baeri	0.078509097	4.677429974	Least concern
Leucippus chlorocercus	0.087920803	7.381662274	Least concern
Leucippus fallax	0.103699785	7.763564666	Least concern
Leucippus taczanowskii	0.242206325	4.677429974	Least concern
Leucochloris albicollis	0.098793529	4.512631328	Least concern
Loddigesia mirabilis	0.090317281	6.404673497	Endangered
Lophornis adorabilis	0.171831902	3.172448462	Least concern
Lophornis brachylophus	NM	2.106255795	Critically endangered
Lophornis chalybeus	0.081769324	3.172448462	Near threatened
Lophornis delattrei	0.086101584	1.839172712	Least concern
Lophornis gouldii	0.092734192	1.845974712	Vulnerable
Lophornis helenae	0.086101584	1.839172712	Least concern
Lophornis magnificus	0.109646328	2.146685795	Least concern
Lophornis ornatus	0.124380139	2.570598712	Least concern
Lophornis pavoninus	0.209283318	2.106255795	Least concern
Lophornis stictolophus	0.092734192	3.527337795	Least concern
Mellisuga helenae	0.228720461	3.125818878	Near threatened
Mellisuga minima	0.110215577	3.125818878	Least concern

Metallura aeneocauda	0.130952756	3.277809589	Least concern
Metallura baroni	0.141681818	1.642144422	Endangered
Metallura eupogon	0.10133667	1.552612255	Least concern
Metallura iracunda	0.195039401	1.760810755	Endangered
Metallura odomae	0.090946022	1.846893422	Least concern
Metallura phoebe	0.109343308	4.975625089	Least concern
Metallura theresiae	0.10133667	1.552612255	Least concern
Metallura tyrianthina	0.141681818	4.625817589	Least concern
Metallura williami	0.152551297	1.642144422	Least concern
Microchera albocoronata	0.098072678	2.226635399	Least concern
Microstilbon burmeisteri	0.126998722	1.029740344	Least concern
Myrmia micrura	0.108561328	1.844558946	Least concern
Myrtis fanny	0.323022494	2.050851446	Least concern
Ocreatus underwoodii	0.090804802	8.002373913	Least concern
Opisthoprora euryptera	0.195039401	7.377654498	Least concern
Oreonympha nobilis	0.138819609	4.91882465	Least concern
Oreotrochilus adela	0.226589022	2.00220137	Near threatened
Oreotrochilus chimborazo	0.312378247	2.239248036	Least concern
Oreotrochilus estella	**0.339522293**	2.766566536	Least concern
Oreotrochilus leucopleurus	0.268810931	1.98010537	Least concern
Oreotrochilus melanogaster	0.160321034	1.98010537	Least concern
Orthorhyncus cristatus	0.268810931	6.628376932	Least concern
Oxypogon cyanolaemus	0.167509635	2.2351895	Critically endangered
Oxypogon guerinii	0.143556799	1.835466833	Least concern
Oxypogon lindenii	0.179965674	2.160004833	Least concern
Oxypogon stuebelii	0.143556799	1.835466833	Vulnerable
Panterpe insignis	0.083213631	**9.325797419**	Least concern
Patagona gigas	**1.896545702**	**14.41417281**	Least concern
Phaeochroa cuvierii	0.153795488	7.763564666	Least concern
Phaethornis aethopygus	0.321941387	1.773151198	Near threatened
Phaethornis anthophilus	**0.343535097**	6.164331282	Least concern
Phaethornis atrimentalis	0.267174361	2.937641413	Least concern
Phaethornis augusti	0.28670674	4.32826082	Least concern
Phaethornis bourcieri	0.251526359	3.20629407	Least concern
Phaethornis eurynome	0.292410101	5.76164082	Least concern
Phaethornis griseogularis	0.244394247	2.900048213	Least concern
Phaethornis guy	**0.433681239**	5.188276249	Least concern
Phaethornis hispidus	0.28670674	3.20629407	Least concern
Phaethornis idaliae	0.244394247	1.925971865	Least concern
Phaethornis koepckeae	**0.343535097**	4.14665807	Near threatened
Phaethornis longirostris	**0.433681239**	4.613276249	Least concern
Phaethornis longuemareus	**0.389177773**	2.048279365	Least concern

Phaethornis malaris	**0.536694804**	5.185861749	Least concern
Phaethornis mexicanus	**0.47645009**	4.613276249	Least concern
Phaethornis nattereri	0.30453697	1.925971865	Least concern
Phaethornis philippii	0.289079136	4.14665807	Least concern
Phaethornis pretrei	0.289079136	4.32826082	Least concern
Phaethornis ruber	**0.347081555**	2.937641413	Least concern
Phaethornis rupurumii	0.267174361	1.773151198	Least concern
Phaethornis squalidus	0.290637312	2.236399046	Least concern
Phaethornis striigularis	0.264432105	2.140534046	Least concern
Phaethornis stuarti	0.291742124	2.140534046	Least concern
Phaethornis subochraceus	**0.402069016**	5.76164082	Least concern
Phaethornis superciliosus	**0.536694804**	5.185861749	Least concern
Phaethornis syrmatophorus	**0.518611183**	7.595383915	Least concern
Phaethornis yaruqui	**1.063886965**	5.188276249	Least concern
Phlogophilus harterti	0.11244969	**9.716365881**	Near threatened
*Phlogophilus hemileucurus**	0.074122095	**9.716365881**	Vulnerable
Polyonymus caroli	0.082026804	7.741546298	Least concern
Polytmus guainumbi	**0.419439567**	**9.002587095**	Least concern
Polytmus milleri	0.137565084	7.319671095	Least concern
Polytmus theresiae	0.216141015	7.319671095	Least concern
Pterophanes cyanopterus	**1.896545702**	**11.20956258**	Least concern
Ramphodon naevius	0.305442651	**15.10168134**	Near threatened
Ramphomicron dorsale	0.261532039	5.745242675	Endangered
Ramphomicron microrhynchum	0.225770527	5.745242675	Least concern
Rhodopis vesper	**0.402069016**	2.050851446	Least concern
Sappho sparganurus	0.130952756	6.978361175	Least concern
Schistes geoffroyi	0.188713452	**10.61290045**	Least concern
Selasphorus ardens	0.098259023	1.139388936	Endangered
Selasphorus calliope	0.151405435	1.522764886	Least concern
Selasphorus flammula	0.081769324	1.275901936	Least concern
Selasphorus platycercus	0.073718296	1.919177219	Least concern
Selasphorus rufus	0.081808794	1.786979886	Least concern
Selasphorus sasin	0.129837109	1.522764886	Least concern
Selasphorus scintilla	0.091815136	1.139388936	Least concern
*Sephanoides fernandensis**	0.192196979	**8.379739381**	Critically endangered
Sephanoides sephaniodes	0.090946022	**8.379739381**	Least concern
Stephanoxis lalandi	0.088872886	6.186068432	Least concern
Sternoclyta cyanopectus	**0.422570542**	4.947320452	Least concern
Taphrolesbia griseiventris	0.183991936	4.977347194	Endangered
Taphrospilus hypostictus	0.145510756	6.688217807	Least concern
Thalurania colombica	0.060088927	3.110264983	Least concern
Thalurania furcata	0.065094453	3.110264983	Least concern

Thalurania glaucopis	0.105569783	3.777084483	Least concern
Thalurania ridgwayi	0.080840664	3.131507323	Vulnerable
Thalurania watertonii	0.085413743	3.403954483	Endangered
Thaumastura cora	0.080948896	1.844558946	Least concern
Threnetes leucurus	**0.33910974**	6.716711832	Least concern
Threnetes niger	0.312691877	5.450881332	Least concern
Threnetes ruckeri	0.33910974	5.450881332	Least concern
Tilmatura dupontii	0.103532803	3.983975539	Least concern
Topaza pella	0.161687231	**11.60919099**	Least concern
Topaza pyra	0.138819609	**11.60919099**	Least concern
Trochilus polytmus	0.278585623	3.581943776	Least concern
Trochilus scitulus	0.216141015	3.581943776	Least concern
Urochroa bougueri	0.221494291	**11.509778**	Least concern
Urosticte benjamini	0.084724753	4.972859413	Least concern
Urosticte ruficrissa	0.088170313	4.972859413	Least concern

CONCLUSÃO GERAL

Em uma escala continental, detectamos que beija-flores pertencentes a linhagens raras e que possuem morfologias únicas tendem a ser os polinizadores exclusivos de algumas plantas, além de evitarem co-extinções, uma vez que realizam interações não redundantes nas redes de interação. Adicionalmente, beija-flores com bico curto e reto, tamanho alar grande, que interagem com maior frequência com seus recursos florais e pertencentes aos clados dos *Bees, Emeralds* e *Mangoes* tendem a ser espécies-chave nas redes de interação entre beija-flores e plantas. E finalmente, beija-flores com bico curto e reto e pertencentes a linhagens evolutivas comuns possuem um maior risco de extinção do que beija-flores de bico longo e curvo e pertencentes a linhagens evolutivas raras. Além disso, a vulnerabilidade à extinção e os tipos de ameaça estão dispersos aleatoriamente na história evolutiva dos beija-flores.

Estes resultados em conjunto sinalizam algumas vulnerabilidades no sistema de polinização entre beija-flores e plantas. São elas (Fig. 1):

(1) as interações raras e a estabilidade do sistema são garantidas por espécies não redundantes evolutiva e morfologicamente, ou seja, sem substitutos na comunidade (Capítulo 1). No entanto, tais espécies apresentam baixa vulnerabilidade à extinção (Capítulo 3), o que pode estar assegurando a existência das interações raras e a estabilidade do sistema.

(2) a convergência entre os atributos de bico das espécies-chave de beija-flores (Capítulo 2) e o efeito da pressão de extinção sobre tais atributos (Capítulo 3), onde beija-flores de bico curto e reto tendem a ser espécies-chave, mas também mais vulneráveis à extinção. Esta convergência sinaliza que a manutenção da

estrutura do sistema pode estar comprometida, já que espécies-chave podem apresentar maior vulnerabilidade à extinção.

(3) o padrão de distribuição das espécies-chave ao longo da história evolutiva dos beija-flores, onde alguns clados possuem maior chance de ser espécies-chave do que os demais (Capítulo 2). Este padrão aponta uma vulnerabilidade ao sistema, uma vez que a perda de um clado pode levar à perda de tais funções. No entanto, o padrão aleatório de distribuição da vulnerabilidade à extinção entre as espécies de beija-flores (Capítulo 3) aponta que a probabilidade de perda de um clado inteiro é baixa.

Em um contexto de conservação das espécies, nossos resultados também ressaltam a necessidade do desenvolvimento de esforços de conservação direcionados para espécies evolutiva e morfologicamente únicas, uma vez que as mesmas desempenham funções exclusivas e auxiliam na manutenção da estabilidade do sistema (Capítulo 1). Esta recomendação reforça que as categorias adotadas pela IUCN não são suficientes para garantir detecção de vulnerabilidade de espécies de beija-flores evolutiva e morfologicamente únicas, já que apenas três dessas espécies são contempladas pela agenda desta instituição (Capítulo 3).

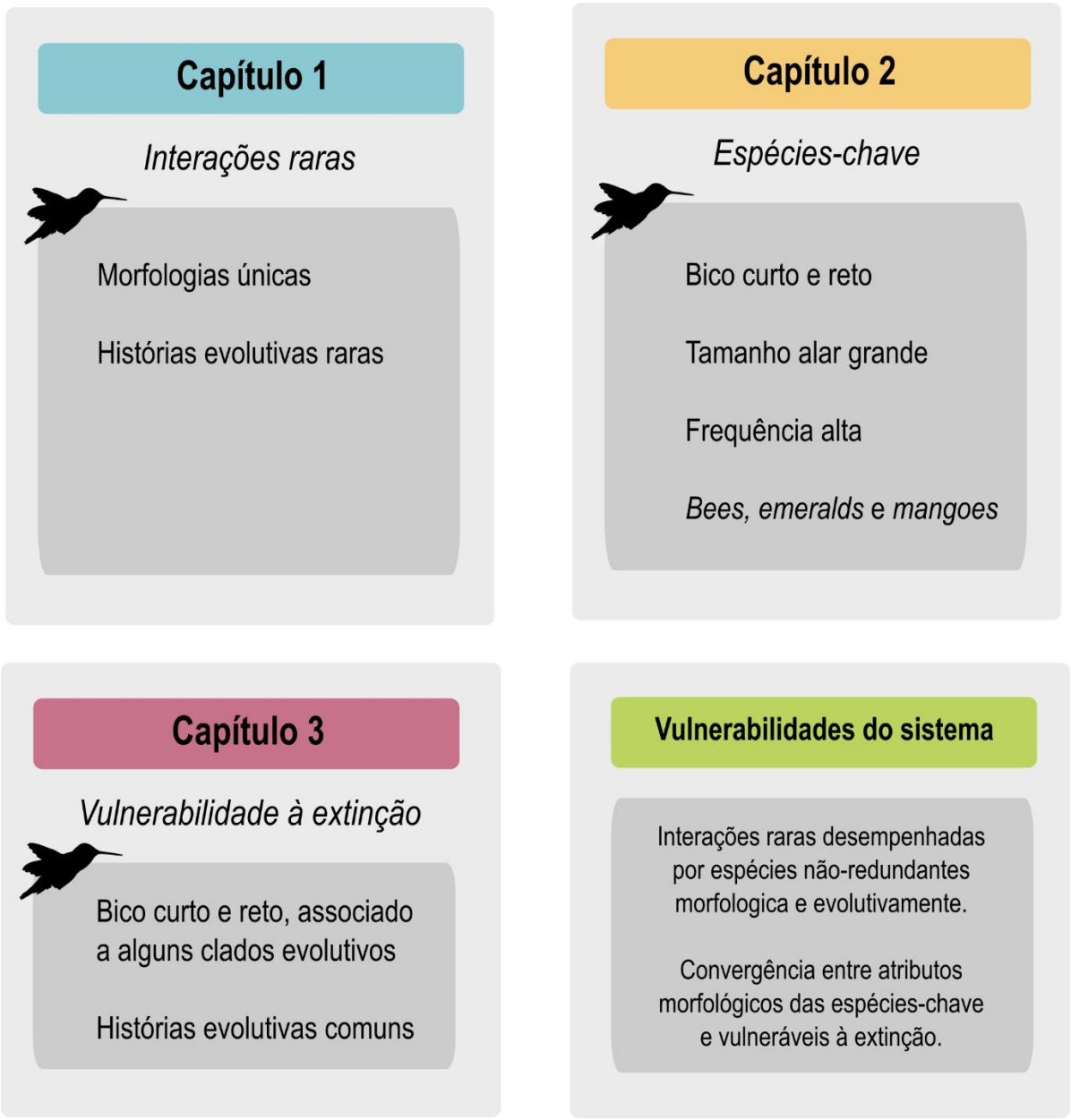

Fig. 1 – Resumo dos principais resultados encontramos nos três capítulos da presente tese e as vulnerabilidades detectadas no sistema de polinização entre beija-flores e plantas.

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APÊNDICES

APÊNDICES DOS CAPÍTULOS 1 e 2

APPENDIX S1 – PLANT-HUMMINGBIRD INTERACTION NETWORKS DESCRIPTIONS

Table S1 – Geographical coordinates and species richness of the plant-hummingbird interaction networks

Network ID	Latitude	Longitude	Hummingbird richness	Plant richness	Data source reference
1	-20.75	-42.92	8	14	Abreu, C.R.M. & Vieira, M.F. (2004) Os beija-flores e seus recursos florais em um fragmento florestal de Viçosa, sudeste brasileiro. *Lundiana*, 5, 129–134.
2	34.22	-116.95	2	4	Alarcón, R., Waser, N.M & Ollerton, J. (2008) Year-to-year variation in the topology of a plant-pollinator interaction network. *Oikos*, 117, 1796–1807.
3	38.98	-106.97	2	2	Ollerton, J., Alarcón, R., Waser, N.M, Price, M.V., Watts, S., Cranmer, L., Hingston, A., Peter, C. & Rotenberry, J. (2009) A global test of the pollination syndrome hypothesis. *Annals of Botany*, 103, 1471–1480.
4	-23.35	-44.83	12	42	Araujo, A.C. (1996) *Beija-flores e seus recursos florais numa área de planície costeira do litoral norte de São Paulo, sudeste do Brasil*. MSc. Thesis. Universidade Estadual de Campinas, Brasil.
5	-19.52	-56.98	4	13	Araujo, A.C. & Sazima, M. (2003) The assemblage of flowers visited by hummingbirds in the “capões” of Southern Pantanal, Mato Grosso do Sul, Brazil. *Flora*, 198, 427–435.
6	19.50	-105.05	5	15	Arizmendi, M.C. & Ornelas, J.F. (1990) Hummingbirds and their floral resources in a tropical dry forest in Mexico. *Biotropica*, 22, 172–180.
7	-20.51	-54.62	7	15	Barbosa-Filho, W. G., & Araujo, A. C. (2013) Flowers visited by hummingbirds in an urban Cerrado fragment, Mato Grosso do Sul, Brazil. *Biota Neotropica*, 13, 21-27.

8	-2.96	-79.10	9	19	Tinoco, B. A., Graham, C. H., Aguilar, J. M. and Schleuning, M. (2016) Effects of hummingbird morphology on specialization in pollination networks vary with resource availability. *Oikos*, 126, 52-60.
9	-2.87	-79.12	8	20	Tinoco, B. A., Graham, C. H., Aguilar, J. M. and Schleuning, M. (2016) Effects of hummingbird morphology on specialization in pollination networks vary with resource availability. *Oikos*, 126, 52-60.
10	-2.83	-79.13	12	19	Tinoco, B.A., Graham, C.H., Aguilar, J.M. and Schleuning, M. (2016) Effects of hummingbird morphology on specialization in pollination networks vary with resource availability. *Oikos*, 126, 52-60.
11	-31.80	-52.42	7	16	Vizentin-Bugoni, J. & Rui, A.M. *Unpublished data.*
12	-23.32	-44.94	13	22	Maruyama, P.K, Vizentin-Bugoni, J., Dalsgaard, B., Sazima, I. & Sazima. M. (2015) Nectar robbery by a hermit hummingbird: association to floral phenotype and its influence on flowers and network structure. *Oecologia*, 178,783–793.
13	-22.50	-44.83	5	32	Canela, M.B.F. (2006) *Interações entre plantas e beija-flores numa comunidade de floresta atlântica montana em Itatiaia, RJ.* Ph.D thesis. Universidade Estadual de Campinas, Brazil.
14	-7.87	-36.40	5	31	Las Casas, F.M.G., Azevedo Júnior, S.M. & Dias Filho, M.M. (2012) The community of hummingbirds (Aves: Trochilidae) and the assemblage of flowers in a Caatinga vegetation. *Brazilian Journal of Biology*, 72, 51–58.
15	-11.48	-41.32	8	27	Moura, A.C. & Machado, C.G. Hummingbirds and their flowers at altitudinal dryland vegetation in Chapada Diamantina, northeast Brazil. *In preparation.*
16	2.67	-76.95	8	27	Ramírez-Burbano, M.B., Stiles, F.G., González, C., Amorim, F.W., Dalsgaard, B. & Maruyama, P.K. (2017) The role of the endemic and critically endangered Coloful Puffleg *Eriocnemis mirabilis* in plant-hummingbird networks of Colombian Andes. Biotropica, 49, 555-564.

17	-13.81	-39.20	13	16	Coelho, A.G. (2013) *A comunidade de plantas utilizada por beija-flores no sub-bosque de um fragmento de Mata Atlântica da Bahia, Brasil.* PhD Thesis, Universidade Estadual de Feira de Santana, Brasil.
18	-3.82	-70.27	15	29	Cotton, P.A. (1998) The hummingbird community of a lowland Amazonian rainforest. *Ibis*, 140, 512–521.
19	22.28	-81.20	2	8	Baquero, A.C. (2014) *Evolutionary and ecological insight into hummingbird-plant communities in the Caribbean.* MSc Thesis. University of Copenhagen, Denmark.
20	15.35	-61.30	3	12	Dalsgaard, B., Martín González, A.M., Olesen, J.M., Ollerton, J., Timmermann, A., Andersen, L.H. & Tossas, A.G. (2009) Plant–hummingbird interactions in the West Indies: floral specialisation gradients associated with environment and hummingbird size. *Oecologia*, 159, 757–766.
21	15.25	-61.37	2	11	Dalsgaard, B., Martín González, A.M., Olesen, J.M., Ollerton, J., Timmermann, A., Andersen, L.H. & Tossas, A.G. (2009) Plant–hummingbird interactions in the West Indies: floral specialisation gradients associated with environment and hummingbird size. *Oecologia*, 159, 757–766.
22	-23.33	-44.83	5	16	Maruyama, P.K, Vizentin-Bugoni, J., Dalsgaard, B., Sazima, I. & Sazima. M. (2015) Nectar robbery by a hermit hummingbird: association to floral phenotype and its influence on flowers and network structure. *Oecologia*, 178,783–793.
23	-23.36	-44.85	11	28	Maruyama, P.K, Vizentin-Bugoni, J., Dalsgaard, B., Sazima, I. & Sazima. M. (2015) Nectar robbery by a hermit hummingbird: association to floral phenotype and its influence on flowers and network structure. *Oecologia*, 178,783–793.
24	-24.56	-47.23	5	24	Fischer, E. *Unpublished data.*
25	12.10	-61.70	2	7	Dalsgaard, B., Martín González, A.M., Olesen, J.M., Ollerton, J., Timmermann, A., Andersen, L.H. & Tossas, A.G. (2009) Plant–

					hummingbird interactions in the West Indies: floral specialisation gradients associated with environment and hummingbird size. *Oecologia*, 159, 757–766.
26	12.10	-61.68	3	7	Dalsgaard, B., Martín González, A.M., Olesen, J.M., Ollerton, J., Timmermann, A., Andersen, L.H. & Tossas, A.G. (2009) Plant–hummingbird interactions in the West Indies: floral specialisation gradients associated with environment and hummingbird size. *Oecologia*, 159, 757–766.
27	1.25	-77.43	9	31	Gutierrez Zamora, E.A. & Rojas Nossa, S.V. (2001) *Dinámica anual de la interacción colibrí-flor en ecosistemas altoandinos del volcán Galeras, Sur de Colombia.* BSc. Thesis. Universidad Nacional de Colombia, Colombia.
28	18.35	-77.65	2	6	Ingversen, T. (2006) *Plant-pollinator interactions on Jamaica and Dominica – the centrality, asymmetry, and modularity of networks.* MSc. Thesis. University of Aarhus, Denmark.
29	-22.28	-41.66	2	8	Fonseca, L.C., Vizentin-Bugoni, J., Rech, A.R., & Alves, M.A.S. (2015) Plant-hummingbird interactions and temporal nectar availability in a *restinga* from Brazil. *Anais da Academia Brasileira de Ciências*, 87, 2163-2175.
30	-27.25	-49.00	6	18	Kohler, G. (2011) *Redes de interação planta-beija-flor em um gradiente altitudinal de Floresta Atlântica no Sul do Brasil.* MSc. Thesis. Universidade Federal do Paraná, Brasil.
31	-27.25	-49.00	4	10	Kohler, G. (2011) *Redes de interação planta-beija-flor em um gradiente altitudinal de Floresta Atlântica no Sul do Brasil.* MSc. Thesis. Universidade Federal do Paraná, Brasil.
32	-27.25	-49.00	4	7	Kohler, G. (2011) *Redes de interação planta-beija-flor em um gradiente altitudinal de Floresta Atlântica no Sul do Brasil.* MSc. Thesis. Universidade Federal do Paraná, Brasil.
33	19.23	-98.97	10	11	Lara, C. (2006) Temporal dynamics of flower use by hummingbirds in a highland temperate forest in México. *Ecoscience*, 13, 23–29.

34	19.28	-98.23	6	4	Lara, C. *Unpublished data.*
35	19.40	-96.80	11	4	Lara, C. *Unpublished data.*
36	0.07	-72.45	8	44	Rosero, L. (2003) *Interações planta/beija-flor em três comunidades vegetais da parte sul do Parque Nacional Natural Chiribiquete, Amazonas (Colombia).* Ph.D. Thesis. Universidade Estadual de Campinas, Brasil. Rosero-Lasprilla, L. & Sazima, M. (2004) Interacciones planta-colibrí en tres comunidades vegetales de la parte suroriental del Parque Nacional Natural Chiribiquete, Colombia. *Ornitologia Neotropical*, 15, 183–190.
37	-12.98	-41.33	7	35	Machado, C.G., Coelho, A.G., Santana, C.S., Rodrigues, M. (2007) Hummingbirds and their flowers in the 'campos rupestres' of Chapada Diamantina, Bahia, northeaster Brazil. *Revista Brasileira de Ornitologia*, 15, 215–227.
38	-13.12	-41.58	7	28	Machado, C.G. (2009) Hummingbirds (Aves: Trochilidae) and their floral resources in an area of caatinga vegetation in the Chapada Diamantina, Bahia State, Northeast Brazil. *Zoologia*, 26, 55–65.
39	-13.12	-41.57	8	11	Machado, C.G. (2014) The hummingbird community and the plants which they visit at a savannah in the Chapada Diamantina, Bahia, Brazil. *Bioscience Journal*, 30, 1578–1587.
40	10.27	-84.08	8	25	Maglianesi, M.A., Blüthgen, N., Böhning–Gaese, K. & Schleuning, M. (2014) Morphological traits determine specialization and resource use in plant–hummingbird networks in the Neotropics. *Ecology*, 95, 3325-3334.
41	10.18	-84.11	9	20	Maglianesi, M.A., Blüthgen, N., Böhning–Gaese, K. & Schleuning, M. (2014) Morphological traits determine specialization and resource use in plant–hummingbird networks in the Neotropics. *Ecology*, 95, 3325-3334.
42	10.44	-84.01	8	22	Maglianesi, M.A., Blüthgen, N., Böhning–Gaese, K. & Schleuning, M. (2014) Morphological traits determine specialization and resource use in plant–hummingbird networks in the Neotropics. *Ecology*, 95, 3325-3334.

43	-25.32	-48.70	10	24	Malucelli, T.S. (2014) *Fatores envolvidos na estruturação das redes de polinização beija-flor-planta em um gradiente sucessional*. MSc Thesis, Universidade Federal do Paraná, Brasil.
44	-18.99	-48.30	8	17	Araújo, F.P., Barbosa, A.A.A., & Oliveira, P.E. (2011) Floral resources and hummingbirds on an island of flooded forest in Central Brazil. *Flora - Morphology, Distribution, Functional Ecology of Plants*, 206, 827-835. Maruyama, P.K., Oliveira, G.M., Ferreira, C., Dalsgaard, B. & Oliveira, P.E. (2013) Pollination syndromes ignored: importance of non-ornithophilous flowers to Neotropical savanna hummingbirds. *Naturwissenschaften*, 100, 1061–1068.
45	-19.16	-48.39	8	35	Araújo, F.P., Sazima, M. & Oliveira, P.E. (2013) The assembly of plants used as nectar sources by hummingbirds in a Cerrado area of Central Brazil. *Plant Systematics and Evolution*, 299, 1119–1133. Maruyama, P.K., Vizentin-Bugoni, J., Oliveira,G.M., Oliveira, P.E. & Dalsgaard, B. (2014) Morphological and spatial-temporal mismatches shape a Neotropical savanna plant-hummingbird network. *Biotropica*, 46, 740–747.
46	-17.78	-48.68	9	12	Machado, A.O., & Oliveira, P.E. (2015) β-Diversity of hummingbird plants in cerrado areas of Central Brazil. *Rodriguesia*, 66, 1-19.
47	19.50	-96.95	12	9	Ornelas, J.F. *Unpublished data.*
48	20.68	-98.76	3	7	Martínez-García, V., Ortiz-Pulido, R. (2014) Redes mutualistas colibrí-planta: comparación en dos escalas espaciales. *Ornitologia Neotropical*, 25, 273–289.
49	20.61	-98.75	5	11	Martínez-García, V., Ortiz-Pulido, R. (2014) Redes mutualistas colibrí-planta: comparación en dos escalas espaciales. *Ornitologia Neotropical*, 25, 273–289.
50	20.13	-98.71	9	23	Díaz-Valenzuela, R. & Ortiz-Pulido, R. *Unpublished data.*

51	20.70	-98.77	2	9	Martínez-García, V., Ortiz-Pulido, R. (2014) Redes mutualistas colibrí-planta: comparación en dos escalas espaciales. *Ornitologia Neotropical*, 25, 273–289.
52	18.13	-66.76	2	11	Dalsgaard, B., Martín González, A.M., Olesen, J.M., Ollerton, J., Timmermann, A., Andersen, L.H. & Tossas, A.G. (2009) Plant–hummingbird interactions in the West Indies: floral specialisation gradients associated with environment and hummingbird size. *Oecologia*, 159, 757-766.
53	17.95	-66.82	2	5	Dalsgaard, B., Martín González, A.M., Olesen, J.M., Ollerton, J., Timmermann, A., Andersen, L.H. & Tossas, A.G. (2009) Plant–hummingbird interactions in the West Indies: floral specialisation gradients associated with environment and hummingbird size. *Oecologia*, 159, 757-766.
54	4.50	-75.60	13	23	Marín-Gómez, O.H. *Unpublished data*.
55	4.54	-75.77	6	14	Cardona, J. & Cardona P.A. (2011) *Uso de recursos florales por el ensamble de aves nectarívoras en el campus de la Universidad del Quindío*. BSc Thesis. Universidad del Quindío, Colombia.
56	-24.18	-47.93	12	36	Rocca-de-Andrade M.A. (2006) *Recurso floral para aves em uma comunidade de Mata Atlântica de encosta: sazonalidade e distribuição vertical*. PhD Thesis. Universidade Estadual de Campinas, Brazil
57	-20.44	-54.65	7	13	Rodrigues, L.C. & Araujo, A.C. (2011) The hummingbird community and their floral resources in an urban forest remnant in Brazil. *Brazilian Journal of Biology*, 71, 611–622.
58	-19.25	-43.52	6	50	Rodrigues, L.C. & Rodrigues, M. (2014) Flowers visited by hummingbirds in the open habitats of the south-eastern Brazilian mountaintops: species composition and seasonality. *Brazilian Journal of Biology*, 74, 659–676.
59	-22.73	-45.58	6	25	Sazima, I., Buzato, S. & Sazima, M. (1996) An assemblage of hummingbird-pollinated flowers in a montane forest in south eastern Brazil. *Botanica Acta*, 109, 149–160.

60	10.67	-61.28	9	57	Snow, B.K. & Snow, D.W. (1972) Feeding niches of hummingbirds in a Trinidad Valley. *The Journal of Animal Ecology*, 41, 471–485.
61	4.53	-73.85	9	13	Snow, D.W. & Snow, B.K. (1980) Relationships between hummingbirds and flowers in the Andes of Colombia. *Bulletin of the British Museum of Natural History (Zoology)*, 38, 105–139.
62	5.90	-73.42	12	22	Snow, D.W. & Snow, B.K. (1980) Relationships between hummingbirds and flowers in the Andes of Colombia. *Bulletin of the British Museum of Natural History (Zoology)*, 38, 105–139.
63	5.92	-73.53	6	13	Snow, D.W. & Snow, B.K. (1980) Relationships between hummingbirds and flowers in the Andes of Colombia. *Bulletin of the British Museum of Natural History (Zoology)*, 38, 105–139.
64	-23.63	-45.85	9	13	Maruyama, P.K, Vizentin-Bugoni, J., Dalsgaard, B., Sazima, I. & Sazima. M. (2015) Nectar robbery by a hermit hummingbird: association to floral phenotype and its influence on flowers and network structure. *Oecologia*, 178,783–793.
65	-17.51	-63.64	6	3	Abrahamczyk, S. & Kessler, M. (2010) Hummingbird diversity, food niche characters, and assemblage composition along a latitudinal precipitation gradient in the Bolivian lowlands. *Journal of Ornithology*, 151, 615–625.
66	-16.96	-65.41	3	6	Abrahamczyk, S. & Kessler, M. (2010) Hummingbird diversity, food niche characters, and assemblage composition along a latitudinal precipitation gradient in the Bolivian lowlands. *Journal of Ornithology*, 151, 615–625.
67	-19.95	-43.90	6	10	Vasconcelos, M.F. & Lombardi, J.A. (1999) Padrão sazonal na ocorrência de deis espécie de beija-flores (Apodiformes: Trochilidae) em uma localidade de campo rupestre na Serra do Curral, Minas Gerais. *Ararajuba*, 7, 71–79.
68	2.52	-76.98	14	19	Ramírez-Burbano, M.B., Stiles, F.G., González, C., Amorim, F.W., Dalsgaard, B. & Maruyama, P.K. (2017) The role of the endemic and critically endangered Coloful Puffleg *Eriocnemis mirabilis* in plant-hummingbird networks of Colombian Andes. *Biotropica*, 49, 555-564.

69	-23.28	-45.05	9	56	Vizentin-Bugoni, J., Maruyama, P.K., Debastiani, V.J., Duarte, L.S., Dalsgaard, B. & Sazima, M. (2016) Influences of sampling effort on detected patterns and structuring processes of a Neotropical plant-hummingbird network. *Journal of Animal Ecology*, 85, 262–272.
70	-0.02	-78.77	19	65	Walther, B.A. & Brieschke, H. (2001) Hummingbird-flower relationships in a mid-elevation rainforest near Mindo, northwestern Ecuador. *International Journal of Ornithology*, 4, 115–135.
71	-13.22	-72.12	6	6	Watts, S., Dormann, C. F., Martín González, A. M., & Ollerton, J. (2016) The influence of floral traits on specialization and modularity of plant–pollinator networks in a biodiversity hotspot in the Peruvian Andes. *Annals of Botany*, 118, 415-429.
72	-12.85	-69.37	8	7	Watts, S., Dormann, C. F., Martín González, A. M., & Ollerton, J. (2016) The influence of floral traits on specialization and modularity of plant–pollinator networks in a biodiversity hotspot in the Peruvian Andes. *Annals of Botany*, 118, 415-429.
73	9.57	-83.73	4	18	Wolf, L.L., Stiles, F.G. & Hainsworth, F.R. (1976) Ecological organization of a tropical, highland hummingbird community. The *Journal of Animal Ecology*, 45, 349–379.
74	9.48	-83.48	5	25	Wolf, L.L., Stiles, F.G. & Hainsworth, F.R. (1976) Ecological organization of a tropical, highland hummingbird community. The *Journal of Animal Ecology*, 45, 349–379.

APPENDIX S2 – INCLUSION METHODS OF THE SPECIES MISSING IN THE PHYLOGENY OF MCGUIRE ET AL. (2014)

Thirteen species of our database (8%) were not included in the phylogenetic hypothesis of McGuire *et al.* (2014). To deal with this phylogenetic uncertainty, we have generated 1,000 hypothetical phylogenies. These phylogenies were built in the SUNPLIN software (Martins et al. 2013) using as a backbone tree the phylogenetic hypothesis proposed by McGuire *et al.* (2014). If the missing species belongs to a monophyletic genus, it was included in the most derived node including all the species of the given genus. However, if the missing species belongs to a polyphyletic genus, it was included in the most derived node including the most taxonomic related species. Descriptions of the node of insertion and the source describing the taxonomic relations of each missing species can be found in the Table S1.

Table S1 – Node of insertion for 13 hummingbird species that were present in our database but were not included in McGuire et al. (2014) phylogeny.

Species	**Node of insertion**	**Taxonomic source**
Glaucis dorhnii	*Glaucis* genus	1
Anopetia gounellei	*Phaethornis* genus	2
Phaethornis squalidus	Sister clade of *Pygmornis* subgenus	2
Phaethornis stuarti	*Pygmornis* subgenus	2
Augastes lumachella	*Schistes geoffroyi*	3
Augastes scutatus	*Schistes geoffroyi*	3
Eriocnemis mirabilis	*Eriocnemis* genus	1
Lophornis magnificus	*Lophornis* genus	1
Mellisuga helenae	*Mellisuga minima*	1
Campylopterus curvipennis	Most derived node including *Campylopterus excellens*	1
Chlorostilbon gibsoni	Most derived node including *Chlorostilbon mellisugus*	1
Chlorostilbon olivaresi	Most derived node including *Chlorostilbon mellisugus*	1
Amazilia cyanifrons	Most derived node including *Amazilia saucerottei*	4

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APPENDIX S3 – MORPHOLOGICAL TRAITS MEASUREMENTS

The morphological measurements were done through the inspection of museum specimens. Where possible, we measured 10 adult specimens of each species, except for *Phaethornis subochraceus* (n=7), *Amazilia chionopectus* (n=5) and *Eriocnemis mirabilis* (n=2). To include possible sexual dimorphism, also, where possible, we measured five females and five males of each species. We were able to do this for 131 species, corresponding to 81% species of our dataset. To avoid intraspecific variation, we measured specimens belonging to the same subspecies or collected from the same site. In total, we have measured 1,584 specimens belonging to 158 species, according to the IOC World Bird list (version 4.4, Gill & Donsker 2014). The specimens were inspected in the following museums: American Museum of Natural History (AMNH – USA), Field Museum of Natural History (FMNH – USA), Museu de Biologia Professor Mello Leitão (MBML – Brazil), Museu Nacional (MNRJ –Brazil), Museu Paraense Emílio Goeldi (MPEG – Brazil), Natural History Museum at Tring (NHMT – United Kingdom), Senckenberg Naturmuseum Frankfurt (SMF – Germany), Smithsonian National Museum of Natural History (USNM – USA), Zoologisches Forschungsmuseum Alexander Koenig (ZFMK – Germany) and Zoologisk Museum, Statens Naturhistoriske Museum (ZMSNM – Denmark). The list of inspected specimens in each museum can be found below (Table S2).

Wing chord was measured from the carpal joint to the tip of the longest primary feather on unflatten wing of the right side, using a digital calliper with a precision to the nearest 0.01 mm.

Bill measurements were done through digital photographs of the right lateral view of the specimens and were conducted on the software ImageJ (Schneider et al. 2012). Each photograph included a ruler, as a scale reference for the measurements. To avoid image

distortions, the camera was positioned perpendicular to the right-sagittal plane of the bill and distant around 15 cm of the specimen. To guarantee that the bill was parallel to the surface, we placed the specimen on a foam base using pins as an external support, to not damage the skins.

Bill length described the chord of the exposed culmen, measured as the linear distance from bill tip to the anterior extension of feathers (in mm, Fig. S1).

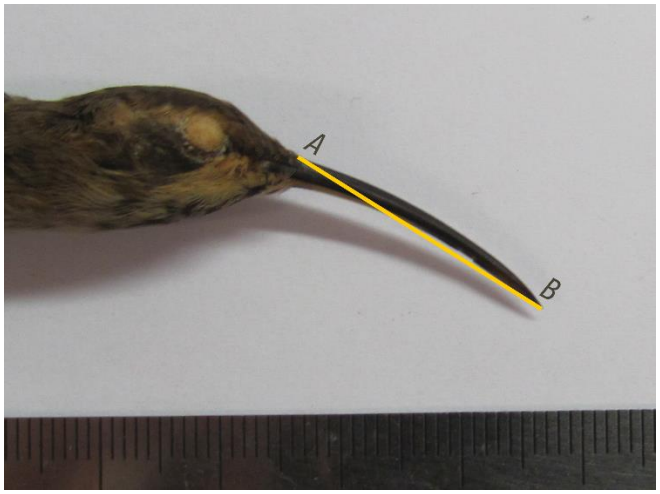

Fig. S1 – Bill length measurement of *Phaethornis rupurumii* (AMNH – 479070) described by the chord of the exposed culmen. A – anterior extension of feathers, B – bill tip.

Bill curvature described the angle of deflection of the exposed culmen, measured by trigonometry rules. First, we placed a scaled grid above the photograph, ensuring that the straight part of the bill was parallel to the horizontal lines of the grid. Then, we measured bill length and deflection length, using the scaled grid. Bill length was measured as a line from the bill tip to the anterior extension of feathers, following the horizontal line from the grid, while deflection length was measured as a line from the bill tip to the bill length's line, creating a 90º angle and, thereby, a right-angle triangle (Fig. S2). Finally, to detect the angle of deflection, we used the tangent rule:

$$tan\,\theta = \frac{deflection\ length}{bill\ length}$$

converting radians to degree.

Bill length and curvature were $\log_{10}$ transformed to achieve normality.

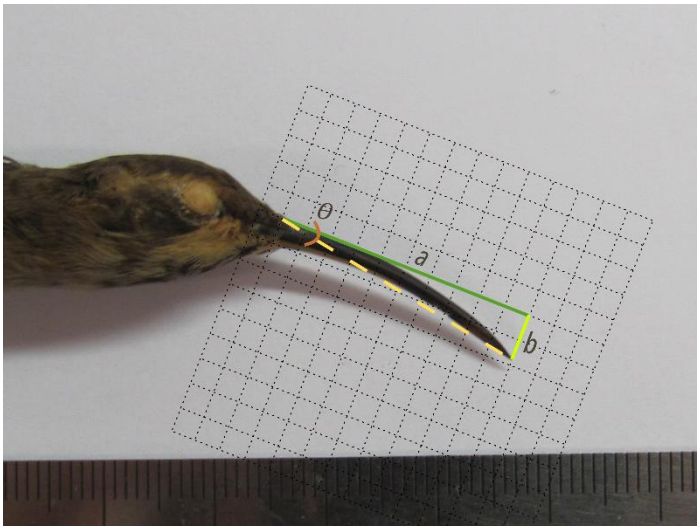

Fig. S2 – Bill curvature measurement of *Phaethornis rupurumii* (AMNH – 479070) described by the angle of deflection. This angle is detected by trigonometry rules using the following parameters: a – bill length's line, b – deflection length's line, *Θ*: angle of deflection.

Table S2 – Museum specimens inspected to measure the morphological traits of hummingbird species.

Species	**Museum code**
Adelomyia melanogenys	ZFMK-9031, ZFMK-B1142fB, ZFMK-B1145af, AMNH-145069, AMNH-234438, ZFMK-9022, ZFMK-9026, ZFMK-9021, ZFMK-9023, ZFMK-9027
Aglaeactis castelnaudii	ZMSNM-103084, ZMSNM-103991, ZMSNM-103995, ZMSNM-103085, ZMSNM-103996, ZMSNM-103993, ZMSNM-103997, ZMSNM-103086, ZMSNM-103992, ZMSNM-103994
Aglaeactis cupripennis	ZMSNM-62997, ZMSNM-63004, ZMSNM-63010, ZMSNM-63008, ZMSNM-62995, ZMSNM-63007, ZMSNM-63003, ZMSNM-63012, ZMSNM-63006, ZMSNM-63014
Aglaiocercus coelestis	ZMSNM-63794, ZMSNM-63793, ZMSNM-63789, ZMSNM-63790, ZMSNM-63796, ZMSNM-63785, ZMSNM-63782, ZMSNM-63781, ZMSNM-63777, ZMSNM-63780
Aglaiocercus kingii	NHMT-1925.12.24.217, NHMT-1969.37.117, NHMT-1969.51.2, NHMT-NL (100), NHMT-NL (99), NHMT-1897.11.12.60, NHMT-1925.12.24.211, NHMT-1925.12.24.213, NHMT-1938.12.20.199, NHMT-1969.38.43
Amazilia beryllina	AMNH-105384, AMNH-480281, AMNH-480279, AMNH-105383, AMNH-91393, AMNH-105394, AMNH-105397, AMNH-105395, AMNH-105386, AMNH-105385
Amazilia candida	USNM-120233, USNM-356840, USNM-155367, USNM-177332, USNM-371660, USNM-59661, USNM-155365, USNM-166074, USNM-155364, USNM-167488
Amazilia chionopectus	MBML-1629, MBML-864, MBML-1628, MBML-1627, MNRJ 33716
Amazilia cyanifrons	AMNH-480044, AMNH-38693, AMNH-126444, AMNH-38692, USNM-310032, USNM-446253, USNM-22236, USNM-595581, USNM-446256, USNM-446251
Amazilia cyanocephala	AMNH-394079, AMNH-394049, AMNH-394046, AMNH-394060, AMNH-153234, AMNH-394050, AMNH-394052, AMNH-394048, AMNH-394051, AMNH-394047
Amazilia fimbriata	AMNH-815899, AMNH-127393, AMNH-479873, MPEG-20928, MPEG-19684, MPEG-20935, MPEG-20941, MPEG-20942, MPEG-20939, MPEG-20943
Amazilia franciae	MBML-1638, MBML-1642, NHMT-1925.12.24.19, NHMT-NL (60), USNM-174082, MBML-1637, MBML-1639, MBML-1640, MBML-1641, NHMT-1925.12.24.18
Amazilia lactea	MPEG-27917, MPEG-27549, MPEG-27551, MPEG-27911, MPEG-27914, MPEG-27912, MPEG-27918, MPEG-27916, MPEG-26382, MPEG-27610
Amazilia leucogaster	MNRJ-18209, MBML-7155, MBML-7301, MNRJ-34329, MNRJ-38135, MNRJ-38136, MBML-7154, MBML-7153, MNRJ-10003, MNRJ-18119

Amazilia rutila	AMNH-394040, AMNH-394043, AMNH-394032, AMNH-394035, AMNH-394027, AMNH-394026, AMNH-394039, AMNH-394041, AMNH-394042, AMNH-394028
Amazilia saucerrottei	ZMSNM-62778, ZMSNM-62776, ZMSNM-62774, ZMSNM-62771, ZMSNM-62775, ZMSNM-62769, ZMSNM-62779, ZMSNM-62780, ZMSNM-62773, ZMSNM-62777
Amazilia tobaci	USNM-151674, USNM-151675, USNM-151676, USNM-310019, USNM-310015, USNM-151677, USNM-595586, USNM-175246, USNM-310017, USNM-310018
Amazilia tzacatl	ZMSNM-64061, ZMSNM-62802, FMNH-249596, FMNH-49185, FMNH-11635, MNRJ-41947, MNRJ-42241, MNRJ-42243, MNRJ-40724, MNRJ-42244
Amazilia versicolor	MPEG-27616, MPEG-27940, MPEG-27607, MPEG-27560, MPEG-27567, AMNH-319374, AMNH-34138, MPEG-27617, MPEG-27580, MPEG-27566
Amazilia violiceps	NHMT-NL(65), NHMT-NL(62), NHMT-NL(67), NHMT-NL(64), NHMT-NL(70), NHMT-NL(68), NHMT-NL(61), NHMT-NL(66), NHMT-NL(69), NHMT-NL(63)
Amazilia yucatanensis	USNM-134932, USNM-134931, USNM-142259, USNM-176195, USNM-158759, USNM-176194, USNM-134933, USNM-134936, USNM-134930, USNM-134939
Anthracothorax dominicus	AMNH-482128, AMNH-101947, AMNH-482115, AMNH-269853, AMNH-101946, AMNH-482132, AMNH-482118, AMNH-101945, AMNH-482113, AMNH-482130
Anthracothorax nigricollis	MNRJ-41459, MNRJ-41460, MNRJ-41454, MNRJ-41458, MNRJ-41456, MNRJ-41451, MNRJ-41450, MNRJ-41462, MNRJ-41463, MNRJ-41461
Anthracothorax prevostii	NHMT-1912.1.1.46, NHMT-1912.1.1.48, NHMT-1912.1.1.53, NHMT-1912.7.1.43, NHMT-1912.1.1.50, NHMT-1912.1.1.51, NHMT-1912.7.1.40, NHMT-1912.7.1.41, NHMT-1912.7.1.44, NHMT-1912.7.1.45
Anthracothorax viridis	USNM-171616, USNM-238805, USNM-354733, USNM-171498, USNM-238806, USNM-171623, USNM-231794, USNM-238807, USNM-231791, USNM-171497
Aphantochroa cirrochloris	MNRJ-48231, MNRJ-41401, MNRJ-41398, MNRJ-41407, MNRJ-41399, AMNH-314059, MNRJ-41402, MNRJ-41405, MNRJ-41404, MNRJ-41398
Archilochus alexandri	AMNH-754528, AMNH-754529, AMNH-754504, AMNH-764484, AMNH-754505, AMNH-29348, AMNH-754513, AMNH-29362, AMNH-29357, AMNH-29346
Archilochus colubris	AMNH-789495, AMNH-484649, AMNH-824191, AMNH-484660, AMNH-361444, AMNH-484643, AMNH-484642, AMNH-484641, AMNH-484645, AMNH-484644
Atthis heloisa	AMNH-754700, AMNH-754698, AMNH-754694, AMNH-754691, AMNH-648897, AMNH-754693, AMNH-754688, AMNH-484963, AMNH-754689, AMNH-648898

Augastes lumachella	MBML-989, MBML-981, MBML-996, MBML-999, MBML-964, MBML-1009, MBML-1007, MBML-1483, MBML-1006, MBML-1011
Augastes scutatus	MNRJ-40135, MNRJ-40155, MNRJ-40141, MNRJ-40121, MNRJ-40153, MNRJ-40187, MNRJ-40186, MNRJ-40185, MNRJ-40189, MNRJ-40190
Boissonneaua flavescens	ZFMK-8849, ZFMK-8850, ZFMK-8851, ZFMK-81385, ZFMK-B1141ca, ZFMK-8852, ZFMK-8848, ZFMK-8843, ZFMK-8847, ZFMK-8844
Boissonneaua jardini	MNRJ-40483, MNRJ-40480, MNRJ-40479, MNRJ-40484, NHMT-1969.37.88, MNRJ-40486, NHMT-1940.12.5.524, NHMT-1953.68.216, NHMT-1969.37.87, NHMT-1925.12.24.92
Calliphlox amethystina	MNRJ-39932, MNRJ-39831, MNRJ-39830, MNRJ-39838, MNRJ-39829, MNRJ-39828, MNRJ-48186, MNRJ-39809, MNRJ-39837, MNRJ-39811
Calliphlox mitchellii	AMNH-117706, AMNH-484599, AMNH-824739, AMNH-117704, AMNH-109538, AMNH-124281, USNM-174568, USNM-595600, USNM-128502, USNM-174569
Calothorax lucifer	ZFMK-9699, ZFMK-9701, ZFMK-9695, ZFMK-9700, ZFMK-9694, ZFMK-9697, ZFMK-9688, ZFMK-9698, AMNH-754444, AMNH-484527
Campylopterus curvipennis	NHMT-NL(85), NHMT-1887.3.22.208, NHMT-NL(83), NHMT-NL(82), NHMT-1887.3.14.36, NHMT-1887.3.22.209, NHMT-NL(84), NHMT-NL(87), NHMT-NL(86), NHMT-1955.6.N.16.106
Campylopterus hemileucurus	ZFMK-6911, ZFMK-6912, ZFMK-6916, ZFMK-6910, ZFMK-6913, ZFMK-6906, ZFMK-6892, ZFMK-6909, ZFMK-6908, ZFMK-6899
Campylopterus largipennis	AMNH-479310, AMNH-479311, MPEG-33543, MPEG-51330, MPEG-51331, MPEG-67275, AMNH-479307, MPEG-31003, MPEG-67274, MPEG-67276
Chaetocercus mulsant	ZFMK-81346, ZFMK-9914, ZFMK-9911, ZFMK-9913, MBML-1529, ZFMK-9909, ZFMK-9917, ZFMK-9904, MBML-1527, MBML-1528
Chalcostigma herrani	ZMSNM-63756, ZMSNM-63757, ZMSNM-63759, ZMSNM-63755, ZMSNM-63758, ZMSNM-63751, ZMSNM-63742, ZMSNM-63745, ZMSNM-63748, ZMSNM-63744
Chlorestes notata	MPEG-5317, MPEG-31831, MPEG-15527, MPEG-15534, MPEG-29720, MPEG-26929, MPEG-30539, MPEG-17818, MPEG-28490, MPEG-72417
Chlorostilbon canivetii	AMNH-47082, AMNH-10438, AMNH-12038, AMNH-12534, AMNH-38792, AMNH-706254, AMNH-47097, AMNH-47096, AMNH-38794, AMNH-38790
Chlorostilbon gibsoni	USNM-410803, USNM-392295, USNM-392294, USNM-401512, USNM-392297, USNM-392156, USNM-410781, USNM-372771, USNM-401511, USNM-372769

Chlorostilbon lucidus	MNRJ-41317, MNRJ-41310, MNRJ-41227, MNRJ-41309, MNRJ-41283, MNRJ-41230, MNRJ-41218, MNRJ-41301, MNRJ-41216, MNRJ-41220
Chlorostilbon maugaeus	USNM-238824, USNM-171607, USNM-171500, USNM-171613, USNM-169116, USNM-238822, USNM-171611, USNM-171610, USNM-231760, USNM-238830
Chlorostilbon mellisugus	USNM-151692, USNM-309884, USNM-329516, USNM-351903, USNM-533671, USNM-329515, USNM-351901, USNM-309883, USNM-329513, USNM-329514
Chlorostilbon olivaresi	No specimens; Rosero-Laspilla, L. unpublished data
Chlorostilbon poortmani	AMNH-481204, AMNH-481206, AMNH-481205, AMNH-54292, AMNH-154447, AMNH-481189, AMNH-47121, AMNH-54311, AMNH-437536, AMNH-54325
Chlorostilbon ricordii	ZFMK-7751, ZFMK-7752, ZFMK-7750, ZFMK-7746, ZFMK-7753, ZFMK-7748, ZFMK-7747, ZFMK-7742, ZFMK-7744, ZFMK-7749
Chrysolampis mosquitus	MNRJ-41104, MNRJ-41061, MNRJ-41101, MNRJ-41107, MNRJ-41063, MNRJ-41049, MNRJ-41046, MNRJ-41096, MNRJ-41110, MNRJ-41095
Chrysuronia oenone	ZFMK-587, ZFMK-81375, ZFMK-84146, ZFMK-571717, ZFMK-1982/43, ZFMK-7537, ZFMK-7539, ZFMK-7540, ZFMK-571715, ZFMK-571718
Clytolaema rubricauda	MNRJ-42319, MNRJ-42340, MNRJ-42317, MNRJ-42320, MNRJ-42302, MNRJ-42283, MNRJ-42286, MNRJ-42306, MNRJ-42309, MNRJ-42308
Coeligena coeligena	ZFMK-8899, ZFMK-8911, ZFMK-8901, ZFMK-8915, AMNH-111593, ZFMK-8904, ZFMK-8905, AMNH-111601, AMNH-111600, AMNH-107845
Coeligena helianthea	ZFMK-8540, ZFMK-8539, ZFMK-10296, ZFMK-8537, MBML-1250, ZFMK-10293, ZFMK-8530, ZFMK-8531, ZFMK-8532, ZFMK-10294
Coeligena iris	FMNH-57568, NHMT-1887.3.22.720, NHMT-1887.3.22.719, NHMT-1969.37.85, NHMT-1887.3.14.334, NHMT-1888.7.25.251, NHMT-1969.37.86, NHMT-1888.7.25.249, NHMT-1887.3.14.333, NHMT-1953.68.227
Coeligena lutetiae	ZFMK-8583, ZFMK-8589, ZFMK-8581, ZFMK-8582, ZFMK-8584, ZFMK-8578, ZFMK-8588, ZFMK-8576, ZFMK-8590, ZFMK-8579
Coeligena prunellei	NHMT-1913.3.20.207, NHMT-1887.3.14.345, NHMT-2002.3.942, NHMT-2002.3.941, NHMT-2002.3.945, NHMT-2002.3.946, NHMT-2002.3.948, NHMT-1887.3.22.768, NHMT-2002.3.944, NHMT-1913.3.20.209
Coeligena torquata	ZFMK-8615, ZFMK-8621, ZFMK-8618, ZFMK-84256, ZFMK-8612, ZFMK-84120, ZFMK-8620, ZFMK-8617, ZFMK-8619, ZFMK-8605

Coeligena wilsoni	AMNH-124151, USNM-173754, USNM-173753, USNM-173758, AMNH-124155, AMNH-154774, AMNH-166889, USNM-173955, USNM-173756, USNM-173752
Colibri coruscans	MNRJ-42157, MNRJ-42170, MNRJ-42159, MNRJ-42172, MNRJ-42156, ZFMK-54724, ZFMK-8043, ZFMK-8040, ZFMK-8020, ZFMK-8034
Colibri delphinae	ZFMK-7957, ZFMK-7959, ZFMK-7965, MBML-91, MBML-89, MBML-90, MBML-88, MBML-92, MBML-100, MBML-96
Colibri serrirostris	MNRJ-41333, MNRJ-41334, MNRJ-41341, MNRJ-41360, MNRJ-41377, MNRJ-41385, MNRJ-41348, MNRJ-41366, MNRJ-41347, MNRJ-42174
Colibri thalassinus	ZFMK-8001, ZFMK-8014, AMNH-811722, AMNH-246080, AMNH-99551, ZFMK-8012, ZFMK-8009, ZFMK-8002, ZFMK-8010, ZFMK-8007
Cyanophaia bicolor	SMF-84478, SMF-84481, SMF-84479, SMF-84480, AMNH-481323, SMF-84472, SMF-84476, SMF-84473, SMF-84474, SMF-84469
Cynanthus latirostris	AMNH-480436, AMNH-480438, AMNH-706248, AMNH-480449, AMNH-480435, AMNH-754828, AMNH-821473, AMNH-480441, AMNH-105406, AMNH-91420
Doryfera ludoviciae	ZFMK-10160, AMNH-179978, ZFMK-6662, ZFMK-6663, ZFMK-84149, ZFMK-10158, ZFMK-6659, ZFMK-6664, ZFMK-87078, MBML-1702
Ensifera ensifera	ZMSNM-63162, ZMSNM-63160, ZMSNM-63163, ZMSNM-63159, ZMSNM-63165, ZMSNM-63150, ZMSNM-63151, ZMSNM-63145, ZMSNM-63157, ZMSNM-63155
Eriocnemis cupreoventris	ZFMK-8914, ZFMK-8909, ZFMK-8915, ZFMK-9627, ZFMK-9623, ZFMK-8907, ZFMK-8906, ZFMK-8910, ZFMK-8908, ZFMK-8913
Eriocnemis derbyi	ZMSNM-63431, ZMSNM-63430, ZMSNM-63435, ZMSNM-63436, ZMSNM-63433, ZMSNM-63429, ZMSNM-63428, ZMSNM-63421, ZMSNM-103978, ZMSNM-63425
Eriocnemis luciani	ZFMK-8871, ZFMK-8873, ZFMK-8872, MNRJ-42118, MNRJ-42118, ZFMK-8868, ZFMK-8870, ZFMK-8876, ZFMK-5918, ZFMK-5910
Eriocnemis mirabilis	AMNH-788368, USNM-533486
Eriocnemis mosquera	NHMT-1887.3.22.1631, NHMT-1887.3.22.1635, NHMT-1887.3.22.1634, NHMT-1897.11.12.93, NHMT-1887.3.22.1630, NHMT-1887.3.22.1632, NHMT-1938.12.20.226, NHMT-1938.12.20.227, NHMT-1938.12.20.195, NHMT-1938.12.20.196
Eriocnemis vestita	ZFMK-8897, ZFMK-8892, ZFMK-8890, ZFMK-8891, ZFMK-9607, ZFMK-8881, ZFMK-8895, ZFMK-8883, ZFMK-8896, ZFMK-8887
Eugenes fulgens	ZFMK-8374, ZFMK-8384, ZFMK-80570, ZFMK-80571, ZFMK-80573, ZFMK-8363, ZFMK-8364, ZFMK-8371, ZFMK-80564, ZFMK-86270

Eulampis holosericeus	AMNH-482181, AMNH-482180, AMNH-482205, SMF-83751, SMF-83752, AMNH-86888, AMNH-482211, AMNH-482204, SMF-83755, SMF-83764
Eulampis jugularis	ZFMK-8206, ZFMK-8208, ZFMK-87035, ZFMK-87036, ZFMK-81676, ZFMK-86275, ZFMK-8202, ZFMK-8200, ZFMK-8198, ZFMK-8201
Eupetomena macroura	AMNH-479441, MPEG-22628, AMNH-242010, AMNH-242040, MPEG-32899, MPEG-22633, MPEG-57825, MPEG-57824, MPEG-57823, MPEG-32898
Eupherusa nigriventris	NHMT-1887.3.22.1758, NHMT-1887.3.22.1761, NHMT-1913.3.20.813, NHMT-1949.58.1231, NHMT-NL (101), NHMT-1887.3.22.1759, NHMT-1887.3.22.1760, NHMT-1913.3.20.812, NHMT-1913.3.20.814, NHMT-1969.25.686
Eutoxeres aquila	SMF-85496, SMF-85477, SMF-85505, SMF-85483, SMF-85497, SMF-85476, SMF-85487, SMF-85495, SMF-85486, SMF-85508
Florisuga fusca	MNRJ-40298, MNRJ-40278, MNRJ-40262, MNRJ-40287, MNRJ-40266, MNRJ-40298, MNRJ-40294, MNRJ-40295, MNRJ-40301, MNRJ-40284
Florisuga mellivora	MPEG-50535, MPEG-50534, MPEG-53838, MPEG-56581, MPEG-62279, MPEG-49824, MPEG-49825, MPEG-62472, MPEG-62473, MPEG-74502
Glaucis dohrnii	MNRJ-18379, MNRJ-39351, MNRJ-39352, MBML-617, MBML-7251, MNRJ-31504, MNRJ-43579, MNRJ-39367, MBML-610, MBML-615
Glaucis hirsutus	MPEG-47362, MPEG-47363, MPEG-50248, MPEG-47361, MPEG-43939, MPEG-47358, MPEG-47354, MPEG-47356, MPEG-47355, MPEG-47357
Haplophaedia aureliae	ZFMK-9648, ZFMK-9652, ZFMK-9649, ZFMK-8928, ZFMK-8929, ZFMK-9638, ZFMK-9645, ZFMK-9639, ZFMK-9643, USNM-425756
Heliactin bilophus	MNRJ-18728, MNRJ-18575, MNRJ-18556, MNRJ-33108, MNRJ-40208, MNRJ-18729, MNRJ-18723, MNRJ-18793, MNRJ-9792, MNRJ-40206
Heliangelus amethysticollis	USNM-372922, USNM-372915, USNM-372918, USNM-372919, USNM-372929, USNM-372925, USNM-372930, USNM-372917, USNM-372931, USNM-372920
Heliangelus exortis	SMF-89071, SMF-89072, SMF-89083, SMF-89073, ZFMK-B1146dE, SMF-89078, SMF-89079, SMF-89081, SMF-89080, ZFMK-9133
Heliangelus viola	AMNH-129496, AMNH-166962, AMNH-129498, AMNH-166981, AMNH-166963, AMNH-166982, AMNH-129494, AMNH-129497, AMNH-166970, AMNH-171119
Heliodoxa aurescens	MPEG-72995, MPEG-62476, MNRJ-38068, MPEG-63434, MPEG-53985, MPEG-69148, MPEG-66009, MPEG-52718, MPEG-41765, MPEG-41617

Heliodoxa imperatrix	NHMT-1897.11.12.67, NHMT-1887.3.22.584, NHMT-1913.3.20.52, NHMT-1869.6.4.2, NHMT-1887.12.17.98, NHMT-1925.12.24.69, NHMT-1887.3.22.586, NHMT-1860.11.26.13, NHMT-1887.3.22.585, NHMT-1887.3.22.588
Heliodoxa jacula	ZFMK-8507, ZFMK-8509, ZFMK-8508, ZFMK-8511, ZFMK-87097, ZFMK-5911, ZFMK-8512, ZFMK-8505, ZFMK-87096, ZFMK-8504
Heliodoxa rubinoides	ZFMK-8480, ZFMK-8470, AMNH-124135, AMNH-166883, AMNH-124134, ZFMK-8476, ZFMK-8473, ZFMK-8468, ZFMK-10267, ZFMK-8472
Heliomaster constantii	ZFMK-9673, ZFMK-9674, AMNH-484516, ZFMK-9664, ZFMK-9666, ZFMK-9668, ZFMK-9670, ZFMK-9667, ZFMK-9671, USNM-309874
Heliomaster longirostris	USNM-238443, USNM-201167, USNM-201171, USNM-201163, USNM-229312, ZFMK-9651, ZFMK-9642, ZFMK-B1155aE, ZFMK-9654, ZFMK-9655
Heliomaster squamosus	MNRJ-40768, MNRJ-40792, MNRJ-48198, MNRJ-40781, MNRJ-40776, MNRJ-40767, MNRJ-18691, MNRJ-40769, MNRJ-41920, MNRJ-40773
Heliothryx auritus	AMNH-130798, AMNH-431959, MNRJ-40317, MNRJ-40306, MNRJ-40322, MNRJ-40309, MNRJ-40313, MNRJ-40320, MNRJ-40310, MNRJ-40312
Hylocharis chrysura	AMNH-321568, AMNH-314104, MNRJ-36595, MNRJ-41643, MNRJ-41644, AMNH-314103, MNRJ-18339, MNRJ-41640, MNRJ-18340, MNRJ-41646
Hylocharis cyanus	MNRJ-41603, MNRJ-41616, MNRJ-41617, MNRJ-41601, MNRJ-41605, MNRJ-29777, MNRJ-32386, MNRJ-41602, MNRJ-41607, MNRJ-41611
Hylocharis leucotis	ZFMK-7465, ZFMK-7468, ZFMK-80583, ZFMK-80584, ZFMK-80585, ZFMK-7454, ZFMK-7455, ZFMK-7456, ZFMK-7458, ZFMK-7462
Klais guimeti	AMNH-179071, AMNH-185010, AMNH-485059, AMNH-185009, AMNH-129532, AMNH-179068, AMNH-129535, AMNH-485055, AMNH-485058, AMNH-485056
Lafresnaya lafresnayi	SMF-87872, SMF-87874, SMF-87875, USNM-174283, USNM-174289, SMF-87871, SMF-87873, SMF-87876, SMF-87877, SMF-87878
Lampornis amethystinus	NHMT-1887.3.22.298, NHMT-1887.3.22.300, NHMT-1912.7.1.70, NHMT-1912.7.1.79, NHMT-NL (102), NHMT-1912.7.1.69, NHMT-1912.7.1.71, NHMT-1912.7.1.72, NHMT-1912.7.1.75, NHMT-1912.7.1.77
Lampornis calolaemus	FMNH-36139, FMNH-72235, FMNH-36138, FMNH-6755, FMNH-72233, FMNH-36140, FMNH-72232, FMNH-6756, AMNH-389721, AMNH-389714
Lampornis castaneoventris	ZFMK-8431, ZFMK-8429, ZFMK-8430, ZFMK-8428, AMNH-37242, ZFMK-8421, ZFMK-8419, ZFMK-8422, ZFMK-8424, ZFMK-8423

Lampornis clemenciae	ZFMK-198265, ZFMK-198266, ZFMK-8404, ZFMK-198268, ZFMK-8403, ZFMK-8398, ZFMK-8400, ZFMK-198260, ZFMK-8402, ZFMK-198261
Lampornis hemileucus	NHMT-1868.2.17.9, NHMT-1887.3.22.314, NHMT-1919.58.1177, USNM-110284, USNM-201152, NHMT-1865.5.19.17, NHMT-1887.3.22.316, NHMT-1949.58.1178, NHMT-NL (140), NHMT-NL (142)
Lamprolaima rhami	NHMT-NL (5), NHMT-NL (7), NHMT-NL (9), NHMT-NL (8), NHMT-NL (6), NHMT-NL (14), NHMT-NL (11), NHMT-NL (10), NHMT-NL (13), NHMT-NL (12)
Lesbia nuna	ZMSNM-63608, ZMSNM-63607, ZMSNM-63604, ZMSNM-63602, ZMSNM-63603, ZMSNM-63597, ZMSNM-63595, ZMSNM-63591, ZMSNM-63592, ZMSNM-63596
Lesbia victoriae	ZFMK-9517, ZFMK-9526, ZFMK-9519, ZFMK-9520, ZFMK-9511, ZFMK-9524, ZFMK-9515, ZFMK-9522, ZFMK-9516, ZFMK-9498
Leucochloris albicollis	AMNH-316632, AMNH-314078, AMNH-316631, MNRJ-41519, MNRJ-41521, MNRJ-41508, MNRJ-41855, MNRJ-41518, MNRJ-41511, MNRJ-41549
Lophornis chalybeus	NHMT-NL (21), NHMT-1895.4.1.109, NHMT-NL (20), NHMT-NL (18), NHMT-NL (19), NHMT-1895.4.1.1008, NHMT-NL (15), NHMT-1887.3.22.1286, NHMT-NL (16), NHMT-NL (17)
Lophornis magnificus	MNRJ-48210, MNRJ-48209, MNRJ-48216, MNRJ-48213, MNRJ-48211, MNRJ-41856, MNRJ-41863, MNRJ-41858, MNRJ-41934, MNRJ-41861
Mellisuga helenae	ZFMK-9814, USNM-233776, USNM-309720, USNM-110682, USNM-233773, ZFMK-9818, ZFMK-9817, AMNH-484683, AMNH-60746, USNM-253723
Mellisuga minima	AMNH-484988, AMNH-37784, AMNH-46607, AMNH-46608, AMNH-484984, AMNH-484985, AMNH-484986, AMNH-37782, AMNH-37783, AMNH-46610
Metallura baroni	AMNH-483780, AMNH-483781, NHMT-1896.2.11.4, AMNH-182355, AMNH-483773, AMNH-483774, AMNH-483775, AMNH-483776, AMNH-483777, NHMT-1896.2.11.3
Metallura tyrianthina	ZFMK-9222, ZFMK-9223, ZFMK-9225, ZFMK-9226, ZFMK-9224, ZFMK-9217, ZFMK-9214, ZFMK-9215, ZFMK-9216, ZFMK-5915
Ocreatus underwoodii	ZFMK-9682, ZFMK-9665, ZFMK-9669, ZFMK-9678, ZFMK-9662, ZFMK-9675, ZFMK-9666, ZFMK-9676, ZFMK-9668, ZFMK-9671
Oreonympha nobilis	NHMT-1946.49.392, NHMT-1946.49.396, NHMT-1946.49.391, NHMT-1946.49.387, NHMT-1946.49.397, NHMT-1946.49.394, NHMT-1946.49.390, NHMT-1946.49.389, NHMT-1946.49.388, NHMT-1946.49.395
Oreotrochilus estella	AMNH-37261, AMNH-229175, AMNH-482475, AMNH-482479, AMNH-482480, ZFMK-8337, ZFMK-8338, ZFMK-8339, ZFMK-8342, ZFMK-81402

Orthorhyncus cristatus	ZFMK-10019, ZFMK-10017, ZFMK-10018, ZFMK-10005, ZFMK-10013, ZFMK-10012, ZFMK-10014, ZFMK-10008, USNM-231768, USNM-231763
Panterpe insignis	AMNH-153955, AMNH-389621, AMNH-38454, AMNH-389607, AMNH-821350, AMNH-389616, AMNH-153952, AMNH-389618, AMNH-389617, AMNH-209642
Phaeochroa cuvierii	NHMT-1912.7.1.299, NHMT-NL (40), NHMT-1912.7.1.296, NHMT-1912.7.1.293, NHMT-1912.7.1.294, NHMT-1912.7.1.297, NHMT-1887.3.22.280, NHMT-1912.7.1.295, NHMT-NL (42), NHMT-NL (41)
Phaethornis bourcieri	MPEG-63707, MPEG-58008, MPEG-52716, MPEG-52033, MPEG-69986, AMNH-816626, MPEG-60487, MPEG-MG 59922, MPEG-52032, MPEG-52549
Phaethornis eurynome	MPEG-27719, MPEG-27722, MPEG-27720, MPEG-MG 40969, MPEG-27717, MPEG-27718, MPEG-28002, MPEG-27723, MPEG-28003, MPEG-27721
Phaethornis gounellei	MPEG-76741, MPEG-MG 67.907, MPEG-76740, MPEG-76790, MNRJ-32153, MNRJ-17965, MNRJ-32119, MPEG-75488, MPEG-75492, MNRJ-43404
Phaethornis guy	ZFMK-6729, ZFMK-6730, ZFMK-6720, ZFMK-6721, ZFMK-6725, ZFMK-6726, ZFMK-6717, ZFMK-6724, ZFMK-6718, ZFMK-6727
Phaethornis hispidus	AMNH-178987, AMNH-178988, AMNH-185162, AMNH-255281, AMNH-237853, MPEG-63627, MPEG-60490, MPEG-63706, MPEG-MG 59925, MPEG-60489
Phaethornis longirostris	AMNH-479181, AMNH-479193, AMNH-37114, AMNH-479177, AMNH-479186, AMNH-479189, AMNH-313431, AMNH-479185, AMNH-479187, AMNH-479188
Phaethornis longuemareus	AMNH-46234, AMNH-37093, AMNH-393932, AMNH-393930, AMNH-393934, AMNH-393931, AMNH-393933, AMNH-393929, AMNH-37089, AMNH-393935
Phaethornis malaris	MPEG-72745, MPEG-42998, MPEG-42469, MPEG-42470, MPEG-42471, AMNH-233749, MPEG-72815, MPEG-72814, MPEG-42468, MPEG-42467
Phaethornis pretrei	AMNH-798780, AMNH-837266, AMNH-127386, AMNH-479056, MNRJ-34378, MNRJ-43775, MNRJ-43779, MNRJ-43785, MNRJ-34319, MNRJ-43780
Phaethornis ruber	MPEG-26409, MPEG-27835, MPEG-47365, MPEG-22112, MPEG-32312, MPEG-35218, MPEG-25103, MPEG-72454, MPEG-33319, MPEG-66623
Phaethornis squalidus	MNRJ-43817, MNRJ-43829, MNRJ-43830, MNRJ-43825, MNRJ-43821, MNRJ-43819, MNRJ-43820, MNRJ-43818, MNRJ-43815, MNRJ-43826
Phaethornis striigularis	MNRJ-41936, MNRJ-41940, MNRJ-41937, MNRJ-41935, MNRJ-42272, MNRJ-42277, MNRJ-42275, MNRJ-42274, MNRJ-42278, MNRJ-42279

Phaethornis stuarti	AMNH-148263, AMNH-148266, AMNH-479249, AMNH-138655, AMNH-148264, AMNH-479246, AMNH-479247, AMNH-479248, AMNH-818053, AMNH-818054
Phaethornis subochraceus	AMNH-127387, AMNH-149425, FMNH-334396, FMNH-334979, FMNH-65390, FMNH-334394, FMNH-334981
Phaethornis superciliosus	MPEG-77589, MPEG-62437, MPEG-77515, MPEG-77516, MPEG-77281, AMNH-275977, AMNH-821442, AMNH-434084, MPEG-62435, MPEG-62442
Phaethornis syrmatophorus	AMNH-478982, AMNH-175925, AMNH-115811, AMNH-478978, AMNH-175923, AMNH-175921, AMNH-478975, AMNH-179990, AMNH-185156, AMNH-478974
Polytmus guainumbi	MBML-783, MBML-786, MNRJ-39845, MNRJ-39844, MNRJ-18743, MBML-1621, MBML-1622, MNRJ-39846, MNRJ-24865, MNRJ-18745
Pterophanes cyanopterus	ZMSNM-63049, ZMSNM-63050, ZMSNM-63047, ZMSNM-63046, ZMSNM-63048, ZMSNM-63039, ZMSNM-63041, ZMSNM-63042, ZMSNM-63040, ZMSNM-16121926
Ramphodon naevius	MNRJ-40885, MNRJ-40883, MNRJ-40926, MNRJ-40895, MNRJ-40886, MNRJ-40875, MNRJ-40868, MNRJ-40887, MNRJ-40878, MNRJ-40898
Ramphomicron microrhynchum	ZMSNM-63652, ZMSNM-63649, ZMSNM-63653, ZMSNM-63647, ZMSNM-63651, ZMSNM-63626, ZMSNM-63616, ZMSNM-63627, ZMSNM-63615, ZMSNM-63622
Selasphorus flammula	USNM-208727, USNM-208724, USNM-208729, USNM-199756, USNM-199456, USNM-208728, USNM-208721, USNM-208726, USNM-208722, USNM-200332
Selasphorus platycercus	USNM-300272, USNM-203596, USNM-154821, USNM-69134, USNM-140303, USNM-140307, USNM-140323, USNM-241342, USNM-140308, USNM-140305
Selasphorus rufus	AMNH-87492, AMNH-361609, AMNH-361706, AMNH-361736, AMNH-361928, AMNH-49367, AMNH-754675, AMNH-49364, AMNH-361739, AMNH-754152
Selasphorus sasin	USNM-529144, USNM-170655, USNM-462930, USNM-563186, USNM-170656, USNM-134374, USNM-203259, USNM-203258, USNM-134375, USNM-190970
Selasphorus scintilla	ZFMK-9871, ZFMK-9887, ZFMK-9872, ZFMK-9884, ZFMK-9882, ZFMK-9884, ZFMK-9874, ZFMK-9877, ZFMK-9875, ZFMK-9873
Stellula calliope	USNM-230582, USNM-94863, USNM-77446, USNM-259620, USNM-269471, USNM-228163, USNM-228164, USNM-228168, USNM-228170, USNM-228167
Stephanoxis lalandi	MNRJ-40253, MNRJ-40247, MNRJ-40252, MNRJ-40234, MNRJ-40251, MNRJ-40210, MNRJ-40243, MNRJ-40212, MNRJ-40242, MNRJ-40237
Thalurania colombica	USNM-163212, USNM-253382, USNM-368825, USNM-149043, USNM-47602, USNM-368774, USNM-372861, USNM-127651, USNM-47858, USNM-446284

Thalurania furcata	MPEG-34537, MPEG-65734, MPEG-64603, MPEG-66423, MPEG-61005, MPEG-34536, MPEG-34538, MPEG-66627, MPEG-64602, MPEG-64964
Thalurania glaucopis	MPEG-27890, MPEG-27630, MPEG-27892, MPEG-27903, MPEG-27902, MPEG-27627, MPEG-25414, MPEG-27888, MPEG-27588, MPEG-27579
Threnetes leucurus	MPEG-52037, MPEG-63704, MPEG-63703, MPEG-63261, MPEG-69984, MPEG-63701, MPEG-52038, MPEG-52039, MPEG-52040, MPEG-63702
Threnetes ruckeri	USNM-606088, USNM-606760, USNM-606087, USNM-606085, USNM-606086, USNM-606077, USNM-606075, USNM-606078, USNM-606079, USNM-606080
Topaza pyra	AMNH-434189, AMNH-802114, NHMT-1997.16.4, MNRJ-41776, NHMT-1997.16.6, NHMT-1997.16.3, NHMT-1997.16.5, NHMT-1997.16.1, ZFMK-8306, NHMT-1888.7.25.158
Trochilus polytmus	ZFMK-81341, ZFMK-87016, ZFMK-87019, ZFMK-87018, ZFMK-88007, ZFMK-96057, ZFMK-96056, ZFMK-87014, ZFMK-87013, ZFMK-84115
Urosticte benjamini	ZMSNM-62906, ZMSNM-62902, ZMSNM-62899, ZMSNM-62897, ZMSNM-62908, ZMSNM-62880, ZMSNM-62877, ZMSNM-62885, ZMSNM-62881, ZMSNM-62886